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1923—1924.

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A Member shall be an officer or employee of a public or private water works, an engineer, chemist or other person qualified to aid or interested in the advancement of knowledge relative to water works.

An Honorary Member shall be a person of acknowledged eminence in some branch of water supply or of engineering.

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An Associate shall be either a person, firm or corporation engaged in manufacturing or furnishing materials or supplies for the construction or maintenance of water works.

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This Association has six regular meetings each year, all of which, except the annual convention in September, are held at Boston.

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New England Water Works Association

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This Association, as a body, is not responsible for the statements or opinions of any of its members.

RAPID SAND FILTRATION AT CAMBRIDGE, MASS.

BY GEORGE A. JOHNSON.*

[*Read September 19, 1923.*]

Twenty-one years ago the first rapid sand filter plant wherein the filter tank units were built of concrete, rectangular in plan, and where the design of the entire works revolutionized the art of rapid sand filter construction, was placed in operation at Little Falls, N. J. This splendid plant set the pace for all future construction of this type, and it is somewhat remarkable that since then the basic features embodied in that plant have not been departed from in the hundreds of installations of rapid sand filters made in the United States in the past twenty years. The Little Falls plant is still doing in a highly satisfactory manner the work for which it was conceived, designed, and erected. When it was built it was freely predicted by many that about all that could reasonably be expected in future plants of this type would be developments of detail, and this has turned out to be generally true.

The speaker was fortunate in having resident charge of the management of the Little Falls plant from the day on which it was placed in operation until all parts of it were running smoothly. After the first six months of continuous operation the management of the works was turned over to Mr. Frank W. Green, who for over twenty years has proved himself an exceptionally competent, ingenious, resourceful superintendent.

On June 28 of this year the new water purification works of the city of Cambridge were dedicated, and that occasion marked an epoch in the history of sanitary engineering in the Commonwealth of Massachusetts. The Cambridge works are the first installation of a municipal water filtration plant of the rapid sand type to be made in that state for the expressed purpose of protecting the health of a community and giving the consumers a clean water.

The plant has been in full operation since April 14 of this year. The results obtained thus far are concordant with the predictions made by the

* Consulting Engineer, New York.

FIG. 1. GENERAL VIEW OF FILTER HOUSE.

speaker when the designs were prepared in 1915, as is borne out by the records of Mr. Melville C. Whipple of Harvard University, who supervises the operation of the works.

Twelve years ago filtration of the Cambridge water supply was recommended by Mr. Frederic P. Stearns, Prof. Hector J. Hughes of Harvard, and Mr. Lewis M. Hastings, City Engineer of Cambridge. Two years later, after an investigation of the watershed, Profs. George C. Whipple and J. W. M. Bunker of Harvard also recommended filtration. In 1915

FIG. 2. FILTERS.

the Cambridge Water Board recommended to the then Mayor and now Superintendent of the Water Department, Hon. Timothy W. Good, that such improvements be made, and the speaker was engaged to engineer the job.

Plans for a rapid sand filter plant were submitted to the Water Board on October 15, 1915, and the ensuing fourteen months were occupied in hearings by the State Board of Health at which various and sundry criticisms by that body of the project as planned were discussed without definite issue. Suspension of all other than absolutely necessary public-works construction during the World War caused further delay until the present Mayor, Hon. Edward W. Quinn, recommended appropriation of the necessary money for construction which was granted by the City Council in 1920. Contracts were executed on June 28, 1920, with Coleman Bros., Inc., of Boston, and the Roberts Filter Manufacturing Co. of Darby, Penn.

Ground was broken early in July, 1920, and thereafter construction proceeded rapidly until stopped by the severe winter of that year, during which no work was done for ninety consecutive days. The plant was finally ready for operation on April 6, 1923, and was started in full operation on April 25, and officially dedicated on June 28, 1923.

Source of Supply. The Cambridge water supply is derived from a watershed lying in the vicinity of Waltham, Weston, and Lincoln, upon which there is a resident population of some 30 000. The drainage area

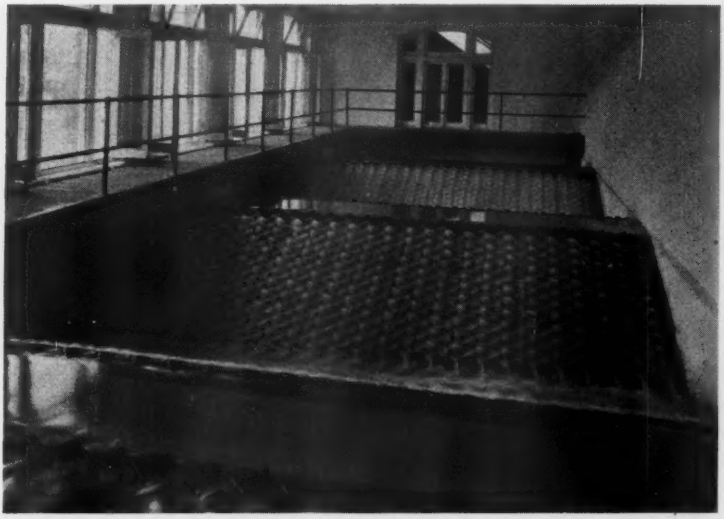


FIG. 3. AËRATOR.

above the diversion point covers 23.57 sq. mi. The waters of Hobbs Brook and Stony Brook which drain this area are impounded in two reservoirs, one on Hobbs Brook and one on Stony Brook. The Hobbs Brook Reservoir has a holding capacity of about 2 500 mil. gal., while Stony Brook Reservoir has an available capacity of slightly under 400 mil. gal. Stony Brook Reservoir, from which Cambridge takes its supply direct, is fed from Hobbs Brook Reservoir through the natural channels of the brooks between the two reservoirs.

Stony Brook Reservoir and the water filtration works are connected by 1.42 mi. of 30-in. cast-iron pipe, 0.91 mi. of 36-in. pipe and 5.2 mi. of 63-in. concrete conduit, respectively. At the lower end of this aqueduct the water passes direct by gravity to the filter plant, the excess being bypassed over a weir into Fresh Pond, which serves as a receiving reservoir. Fresh Pond drains an area of about one square mile and has an available storage capacity of about 400 mil. gal. of water.

Water Consumption. Very careful inspection of plumbing fixtures, and the prosecution of other lines of water conservation endeavor, have been instrumental, even in the absence of complete metering, in keeping the water consumption in Cambridge at a remarkably low figure. At this date the consumption averages about 100 gal. per capita. In the past twenty years the population has increased about 20 per cent and the water consumption about 27 per cent.

Quality of the Raw Water Supply. Numerous investigations of sanitary conditions on the catchment area have been made in the past twenty or more years, notably by the late Frederic P. Stearns, Prof. William T. Sedgwick and more particularly by Prof. George C. Whipple of Harvard University. The conclusions arrived at as a result of these investigations were practically the same in all cases. Professor Whipple's investigation was made in 1912–13.

The watershed is similar to many others in the potentialities offered for dangerous contamination. From a population of about 120 per sq. mi. this danger is always present. There are numerous cases where the brooks run parallel and close to highways, affording easy access to the streams of dangerous polluting matter.

It is necessary to make plain that there are strict sanitary regulations operative for safeguarding the water supply of Cambridge. The difficulties of enforcing such regulations are clearly obvious, and it has long been recognized that their strict enforcement is impossible. Furthermore, no matter how diligent and efficient a watershed patrol may be it cannot prevent the pollution of a water supply derived from surface sources, whether the catchment area be populated or not. Protection of the Cambridge supply by purchase of the entire watershed was out of the question, and in consequence the Water Board has always continued its efforts toward minimizing the pollution of the raw supply, and such efforts are even now continued although a sure safeguard against the entrance of disease germs into the distribution system of Cambridge is afforded by the filter plant at Fresh Pond. The Water Board decided, as did the engineers who investigated the problem before the speaker, that no matter how carefully the watershed is patrolled, or how little chance there is of dangerous polluting matter entering the supply, the only way in which the health and comfort of the people of Cambridge could be adequately conserved was through the medium of competent filtration, which would not only make the water hygienically pure, but free of color, offensive odor and taste, and clean.

The color of the Cambridge water supply is very similar in character and amount to that of the Passaic River water above the filter plant at Little Falls. The color is of vegetable origin, coming from decaying vegetable growths in the swampy areas on the watershed. These swampy areas have been drained to some extent by ditching, but further work along this line is highly advisable because by the swift draining of such

areas the color of the raw water could be reduced to a material degree and a substantial economy in the amount of chemical required for the removal of the color at the filter plant could be effected.

Some have claimed that the natural purification effected in the storage reservoirs is sufficient treatment to safeguard the purity of the supply. In Hobbs Brook Reservoir the salutary effect of such purification by storage is far more pronounced than in Stony Brook Reservoir, which is long and narrow and allows swift passage of the water through it, especially following heavy rains on the watershed, accompanied by a strong north wind. In this regard Professor Whipple in his report to the Water Board, dated December 17, 1913, drew pointed attention to the fact that water from the most dangerous feeder of Stony Brook conceivably could reach Fresh Pond in Cambridge within 48 hr., and possibly in a considerably shorter time than that.

A long series of analyses of the reservoir waters discloses an abundance of microörganisms, as would be expected, and it is such algæ growths which have imparted to the water supply of Cambridge the obnoxious tastes and odors of which the people have so frequently complained.

In the past all of the water supply was delivered direct into Fresh Pond, adjacent to which is located the new filter plant. From Fresh Pond the water flowed by gravity into the pump well, thereafter being forced into the distribution system and Payson Park Reservoir. The storage in Fresh Pond, which covers an area of some 170 acres, amounts to about one month's supply. The conformation of the shores of the pond encourage material purification of the water, and there is little opportunity for gross pollution from the some 9 000 persons actually resident on the territory adjacent to Fresh Pond. At the present time Fresh Pond is not utilized as a source of supply except at times when the gravity flow to the filter plant direct from the conduit is insufficient to meet the demand.

Fresh Pond is a favorable breeding ground for algæ. Algæ growths not only impart disagreeable tastes and odors to the water, but the organisms and débris resultant from such growths finding their way to the filters speedily clog them, thereby occasioning very frequent washing with the accompanying increased cost of operation. Sharp measures are always necessary during spring and summer months to check the development of algæ. Treatment with copper sulphate of the waters of Fresh Pond, as well as those of the upper reservoir, destroys the objectionable growths.

Summed up it may be said that the raw water supply of Cambridge is derived from a quite heavily populated watershed, and that the raw supply is always open to the possibilities of dangerous contamination. The water is soft, the hardness averaging about 30 parts and ranging from about 20 to 40 parts per million, of which about one-half is temporary hardness. The color of the raw supply ranges from a maximum of about 50 to a minimum of about 20 parts per million and less, and averages about 25 parts per million. The water is substantially free from high amounts of

turbidity. The bacterial content and the B. coli count are about what would be expected in a water of this character drawn from a watershed such as that described.

Purification Works. The purification plant has a capacity of 14 mil. gal. per 24 hr. and can readily be enlarged to 16 mil. gal. The raw supply is delivered to the plant by gravity through 1 480 ft. of 42-in. cast-iron pipe, leading from a weir chamber situated on the lower end of the 63-in. brick conduit which formerly fed Fresh Pond direct from Stony Brook Reservoir. At times when the gravity flow to the plant is insufficient the deficiency is made up by taking water from Fresh Pond through a 42-in. intake pipe 320 ft. long connecting with the old draft conduit, and pumping through a 30-in. pipe to the 42-in. main supply line.

The purification works are located in Kingsley Park, on city land lying between the Fitchburg Railroad and Fresh Pond, about 300 ft. northwesterly from Fresh Pond Station and 200 ft. from Fresh Pond. The purification works cover an area of about 1.6 acres. The plant consists of a covered coagulating sedimentation basin, 10 rapid sand filter units, filtered-water aërator, clear-water basin, sterilizing equipment, wash-water receiving basin, low-lift pumping equipment and superstructures. The main structures are chiefly reinforced concrete of flat slab and beam and slab type. The superstructure is brick and the roof is concrete.

The sedimentation basin is constructed of concrete, and is 137 ft. by 96 ft. and 16 ft. in effective depth. Its working capacity is 1.5 mil. gal., equivalent to a 2.5 hr. flowing-through period when the plant is operating at full capacity. The basin is divided into two bays of equal size by a longitudinal party wall. A distributing weir and downward baffle are provided at the inlet end. At the outlet end of the basin the water flows off over a skimming weir. Other accessories of the basin are distributing pipes for returned wash water, a sludge pump, overflow and gate chambers. The basin is separated from the clear-water basin by an earth bank 20 ft. thick which ensures freedom from any possibility of pollution of the filtered water from this source. There are 10 filter units, built monolithically of concrete, and laid out in one row with a pipe gallery and operating platform along one side. The clarified water from the sedimentation basin is applied to the filters from a concrete flume running parallel to the pipe gallery. The filter tank units are 20 ft. by 24 ft. by 9 ft. deep, and each has a filtering area of 480 sq. ft. Thus when operating at normal capacity each filter unit handles 1.4 mil. gal. per 24 hr.

The filtering medium is 27 in. in thickness overlying 9 in. of graded gravel. The buildings and filter equipment are in general conformity with customary up-to-date modern practice, although somewhat more elaborate in certain particulars than that observed in most filter plants. The city officials believed with the speaker that the hub of the intellectual universe was deserving of the best the art afforded in the line of a water-purification plant designed to protect the health and support the civic

pride of such a community. The filter floor is of the type known as the "Wheeler Bottom."

A feature of this plant, which however has been made use of in a few other places, is the idea of returning to the sedimentation basin the wash water discharged from the filters. This is effected by collecting the raw wash water as discharged in a covered concrete tank 37.5 ft. in diameter and 10 ft. deep. When filter washing commences the wash-water return pump in this basin is started, returning the wash water to the inlet end of the sedimentation basin. There is a 12-in. overflow from this basin leading to the city sewer.

The results of the use of the returned wash water are twofold, namely, encouragement of coagulation activities in the coagulating basin through the medium of the returned wash water which is heavily charged with precoagulated matters and which operate as nuclei in the formation of new flocs; and, second, in conserving to the utmost the limited water supply derivable from the restricted catchment area. The practice is also of benefit in guarding against overloading the city sewer with waste water at inopportune times.

The clear-water basin is a covered reservoir having a capacity of 4 mil. gal. It is 274 ft. by 147 ft. in plan and carries a maximum depth of water of 13 ft. when the aërator is in operation. The basin extends under the filters on one side, a filtered water conduit runs under the pipe gallery, and the basin is so arranged that it can be by-passed if necessary.

The sterilizing equipment is assembled in the head house, chlorine being applied to the aërated filtered water. An aërator consisting of sloping concrete slabs in which are set sharp baffles arranged herringbone fashion, releases free carbonic acid and offensive tastes and odors from the water.

The pumping equipment consists of one 4-mil. gal., two 6-mil. gal., and one 10-mil. gal. horizontal centrifugal pumping units to deliver raw water from Fresh Pond to the sedimentation basin when the gravity supply from Stony Brook is insufficient. There are two horizontal centrifugal pumps, each having a capacity of 1 100 gal. per min., which deliver filtered water into a wash-water storage tank for use in cleaning the filters. There are two vertical centrifugal pumps, each of a capacity of 1 700 gal. per min., which are utilized to return the used wash water to the sedimentation basin.

All pumps and chemical mixing machinery are driven by alternating-current, direct-connected motors, on a 550-volt, 3-phase, 60-cycle current.

The wash-water tank is 29 ft. in diameter and 34 ft. in height, and holds sufficient water to wash two filters in succession. Wash-water pumps start automatically to replenish the wash-water storage tank as soon as washing of a filter begins.

The superstructure is a two-story building 223 ft. by 71 ft. The wash-water tank is enclosed in a central tower. The first story of the

main building is built of concrete and the second is faced with tapestry brick with synthetic stone trim. The roof is of concrete covered with waterproof membrane. This building houses the filters, administration offices, laboratories, chemical storage, wash-water tank, pumps and all other machinery and devices.

Purification Process. The purification process is practically identical to that followed in so many other places, and needs no detailed description here. The water first enters the sedimentation basin at the entrance to which sulphate of alumina solution is added. The treated water is diverted at the entrance to the basin downward to the bottom thereof by means of a baffle, and thereafter passes slowly through the basin. The partially clarified water leaves the basin over a submerged wall which serves as a skimming weir. Thence the water flows through a 48-in. pipe to the influent flume of the filters, being admitted thereto through hydraulically-operated sluice gates on each individual filter unit. Passing the filters the water is collected by the strainer system, and passed through registering controllers which maintain a constant rate of filtration. The filtered water then flows into a flume below through tubes with trapped outlets. Leaving the flume the filtered water passes over the aërator, thereafter receiving a dose of liquid chlorine as a final step in bacterial purification. The ultimate product flows into the clear-water basin and thence by gravity to the Fresh Pond pumping station for distribution.

At times, particularly following heavy rains or thaws on the watershed, the alkalinity of the raw water falls so low as to make it necessary to add a small quantity of soda ash to the water as it flows through the 42-in. main supply line at a point about 100 ft. from the sedimentation basin. This compensates for deficient alkalinity and ensures complete decomposition of the added coagulant.

The filters are washed by passing currents of filtered water at high velocity up through the filter beds. The dirty water is collected in gutters at the top of the filters and drained off to the receiving basin whence it is returned by pumping to the inlet end of the sedimentation basin.

All valves in the filter and washing process are controlled from operating tables which are uncommonly substantial and ornate, being constructed of marble, bronze and plate glass.

The sludge which accumulates in the sedimentation basin is from time to time pumped out by means of a vertical-shaft, motor-driven centrifugal pump, having a capacity of 1 500 gal. per min. This sludge is discharged into a nearby sewer.

Cost of Construction. In numerous particulars this plant differs from others, and these facts tended to make its first cost greater than usually is the case. Kingsley Park is particularly attractive and demanded architectural features more ornate than in many places would be considered necessary. Furthermore, the Fresh Pond pumping station is operating on a 16-hr. schedule out of every 24, and this made it necessary to

provide an abnormally large clear-water basin in which to store water against a 50 per cent overdraft during the pumping period. The aërator and the wash-water receiving tank with piping connections and pumping equipment are other unusual items. The long connecting pipe lines furnish still another abnormal item of expense.

The figures in the following table furnish an analysis of the cost of these works:

COST OF CAMBRIDGE WATER FILTRATION PLANT.
(ANALYSIS FROM FINAL ESTIMATE.)

Item.	Bid Price.	Net Cost for Additions and Extra Work.	Final Estimate.	Properly Chargeable to Filter Plant.
A Pipe lines outside of masonry structures	$90 000.00	$3 733.56	$93 733.56	$25 000.00*
B Sedimentation basin, substructures of buildings and filter structures	328 000.00	35 406.05	363 406.05	271 000.00†
C Superstructures	80 000.00	3 418.61	83 418.61	83 418.61
D Filter equipment	225 900.00	207.00	225 693.00	225 693.00
E Chlorinator	1 400.00	0.00	1 400.00	1 400.00
Total	$725 300.00	$42 351.22	$767 651.22	$606 511.61

Rated capacity of filter plant	14 000 000 gal. daily
Bid price	$725 300.00
Final estimate	767 651.22
Extra work	42 351.22 (5.8 per cent)
Allocated cost of filter plant	606 511.61
Cost per mil. gal. rated capacity	43 322.26

The execution of this project, which means so much to Cambridge and gives equal promise to other Massachusetts communities, is the result of the great foresight and untiring persistence of ex-Mayor Good, Mayor Quinn, President Scully and other members of the Water Board, supported by the Common Council and citizens of the City of Cambridge. Credit for whatever commendable engineering features the works may possess is due to the combined efforts of all those connected with the work. The speaker's associate, Mr. Stevens, was in active supervisory charge of design and construction; and to the resident engineer, Mr. Fred S. Childs, great credit is due. The quality of the finished works bears eloquent testimony to the excellent work of the contractors.

The speaker has purposely avoided details in the foregoing remarks, preferring that they should be furnished by those immediately responsible for them. He therefore requests, before general discussion starts, that

* Estimated cost of all outside piping, $89 850. Figure given is for normal amount of such pipe lines.
† Estimated cost of 4 mil. gal. clear-water basin, $138 400. Allowance of $45 993.95 made for a basin of normal size.

remarks be requested from his associate, Mr. Stevens; from Mr. Smulski on the specific question of steel reinforcement; from Mr. Whipple on operating procedure, costs and results; from Superintendent Good, President Scully, and from Mayor Quinn.

DISCUSSION.

HAROLD C. STEVENS.* It is the purpose of this discussion to supplement Colonel Johnson's paper, as has been indicated by him, with a more detailed description of the principal elements of the Cambridge filters.

The location in Kingsley Park is favorable as to topography and proximity to a railroad station, and to the existing pumping station and its intake from Fresh Pond. The elevation of the plant was fixed within narrow limits by the elevation of the gatehouse on Stony Brook conduit, it being just possible by raising the water level in the gatehouse to send the water by gravity through the plant and to deliver it at an elevation within the suction limit of the main high-service pump.

It was necessary to deepen the pump suction well to correspond with the elevation of the bottom of the clear-water basin, and to provide special devices to control the suction lift to meet certain peculiarities of the pump. This was accomplished without seriously interfering with service to the city from the usual source.

The gravity supply is limited, and in order to provide for periods of high consumption or a temporary heavy draft to meet operating conditions at the pumping station, and to make available the storage capacity of Fresh Pond, a connection was made to the old intake whereby the raw water supply may be drawn by gravity to a pump well at the filter plant and be delivered as needed, by low-lift motor-driven centrifugal pumps to a point on the main supply line about 100 ft. from the sedimentation basin, far enough to permit soda-ash solution introduced into the main to become well mixed with the raw water before it reaches the entrance to the sedimentation basin where alum is applied. The use of soda ash is necessary during the time of year when the natural alkalinity of the water is too low for proper coagulation to take place.

Venturi meters are provided on the gravity supply line and on the force main of the pumped supply.

The present water supply from Stony Brook conduit is a little less than the nominal capacity of the filters and a little more than the city needs, but it is possible by cleaning the cast-iron portion of the conduit to increase its flow about 25 per cent which is sufficient to avoid the use of low-lift pumps almost entirely.

Plate I shows a general plan of the filter plant.

---

* Consulting Engineer, New York.

Sedimentation Basin. Water enters at the bottom of a chamber at one end through a hydraulically-operated shutter valve, float controlled, for maintaining a practically constant water level in the sedimentation basin. The coagulant is applied at this point through a perforated grid. The water rises in the chamber, passes into channels running across the end of each compartment of the sedimentation basin, flows over the edge of the channels, is turned downward by a baffle and thence flows through the basin. Either or both compartments of the basin may be used. The inlet channels have openings in the bottom through which part of the flow passes and carries away any sediment that otherwise would accumulate in the channels. Channels across the outlet end receive water over their edges from the surface of the settled water, and deliver into an effluent chamber and thence through a pipe to the filter influent flume.

A chamber at the inlet end of the sedimentation basin receives returned waste wash water, and distributes it across the basin through perforated pipes near the bottom and just beyond the baffle. At the outlet end is a chamber containing a motor-driven centrifugal sludge pump, and an overflow chamber discharging through a 12-in. pipe into Fresh Pond. This pipe also serves for draining the basin down to pond level in connection with cleaning operations. A system of piping, connected with the city force main is provided for flushing the basin with hose.

Filters. The ten filters are arranged in a single row with operating floor and pipe gallery alongside. Foundations for six future filters are provided so that extension can be made without seriously interfering with the operation of the plant. A concrete influent flume supplies all filters through independent valved connections discharging into the waste-water compartment across the front of each filter, whence the water flows through the gutter openings and spreads gently over the sand beds, filters through the sand into a collecting system underneath and thence through piping and rate controllers to the clear-water flume below.

The clear-water flume may deliver over the aërator to the clear-water basin, the usual way, or it may without aëration deliver either to the clear-water basin or direct to the pumping station.

Chlorine is applied at the entrance to the clear-water basin.

All valves ordinarily used are hydraulically operated and are controlled in the usual way from operating tables placed on the floor above, these tables also carrying the indicating and recording gages appurtenant to each filter.

Along with the operating tables are provided a wash-water meter register, a depth gage for the clear-water basin, and a sampling table where samples of the water in its various stages of treatment may be drawn for analysis. In the pipe gallery are cocks for taking samples of filtered water from each individual filter.

Clear-Water Basin. The clear-water basin has a capacity of 4 mil. gal., including the clear-water flume. This is exceptionally large in order to

PLATE I.

N. E. W. W. ASSOCIATION.

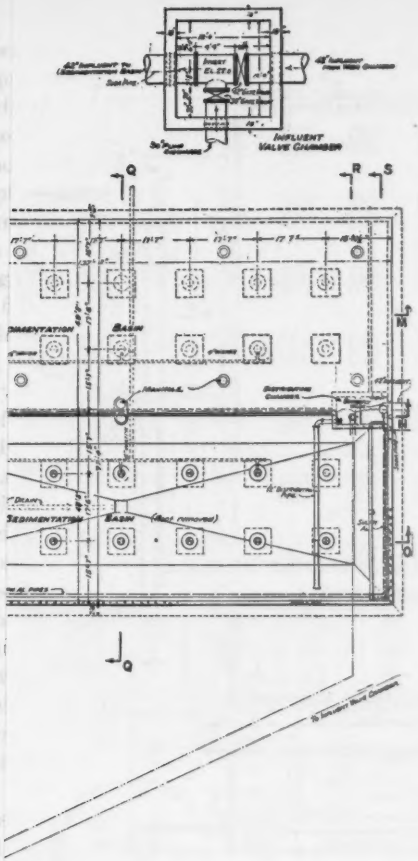
VOL. XXXVII.

JOHNSON

RAPID SAND FILTRATION,

CAMBRIDGE, MASS.

DISCUSSION — STEVENS.



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Filters. The ten filters are arranged in a single row with operating floor and pipe gallery alongside. Foundations for six future filters are provided so that extension can be made without seriously interfering with the operation of the plant. A concrete influent flume supplies all filters through independent valved connections discharging into the waste-water compartment across the front of each filter, whence the water flows through the gutter openings and spreads gently over the sand beds, filters through the sand into a collecting system underneath and thence through piping and rate controllers to the clear-water flume below.

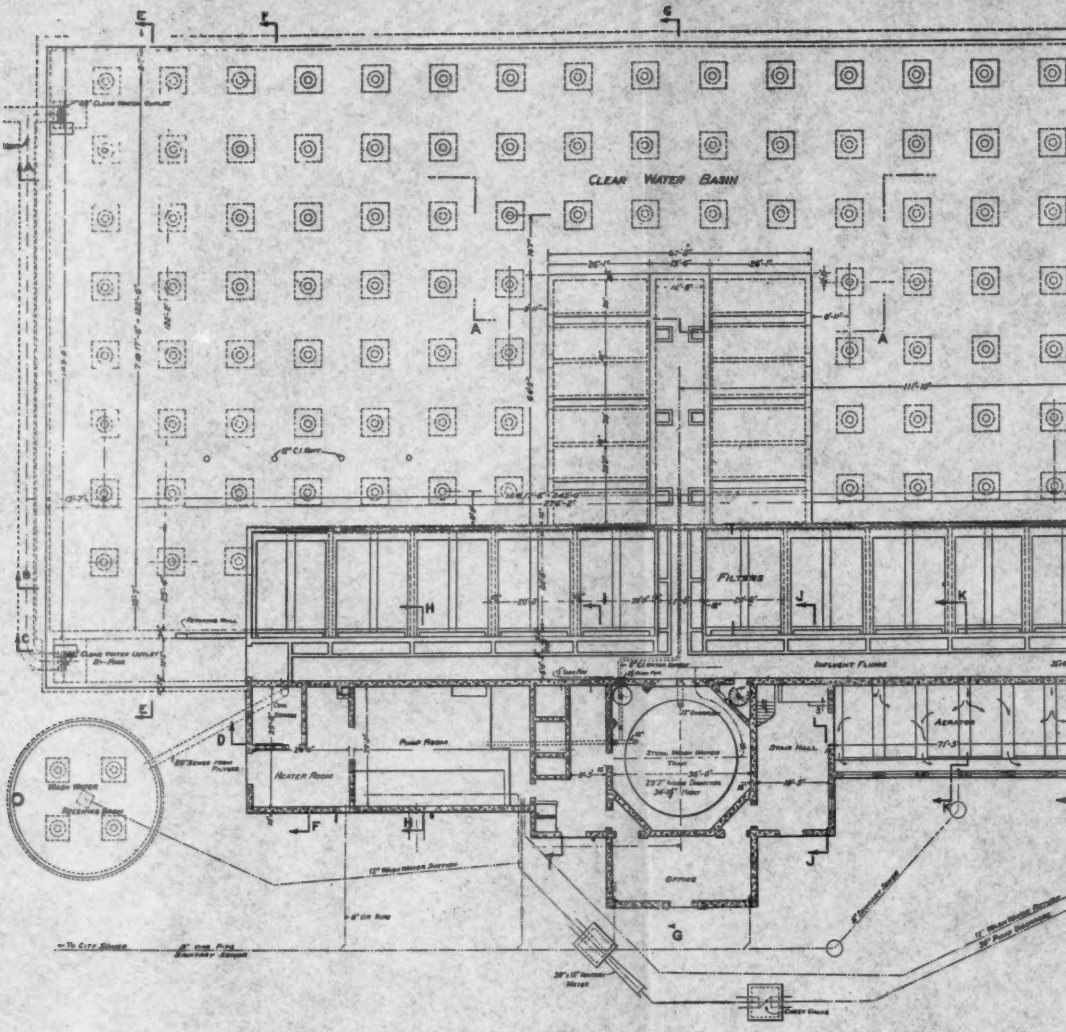
The clear-water flume may deliver over the aërator to the clear-water basin, the usual way, or it may without aëration deliver either to the clear-water basin or direct to the pumping station.

Chlorine is applied at the entrance to the clear-water basin.

All valves ordinarily used are hydraulically operated and are controlled in the usual way from operating tables placed on the floor above, these tables also carrying the indicating and recording gages appurtenant to each filter.

Along with the operating tables are provided a wash-water meter register, a depth gage for the clear-water basin, and a sampling table where samples of the water in its various stages of treatment may be drawn for analysis. In the pipe gallery are cocks for taking samples of filtered water from each individual filter.

Clear-Water Basin. The clear-water basin has a capacity of 4 mil. gal., including the clear-water flume. This is exceptionally large in order to



GENERAL PLAN OF FILTRATION PLANT.

PLATE I.

N. E. W. W. ASSOCIATION.

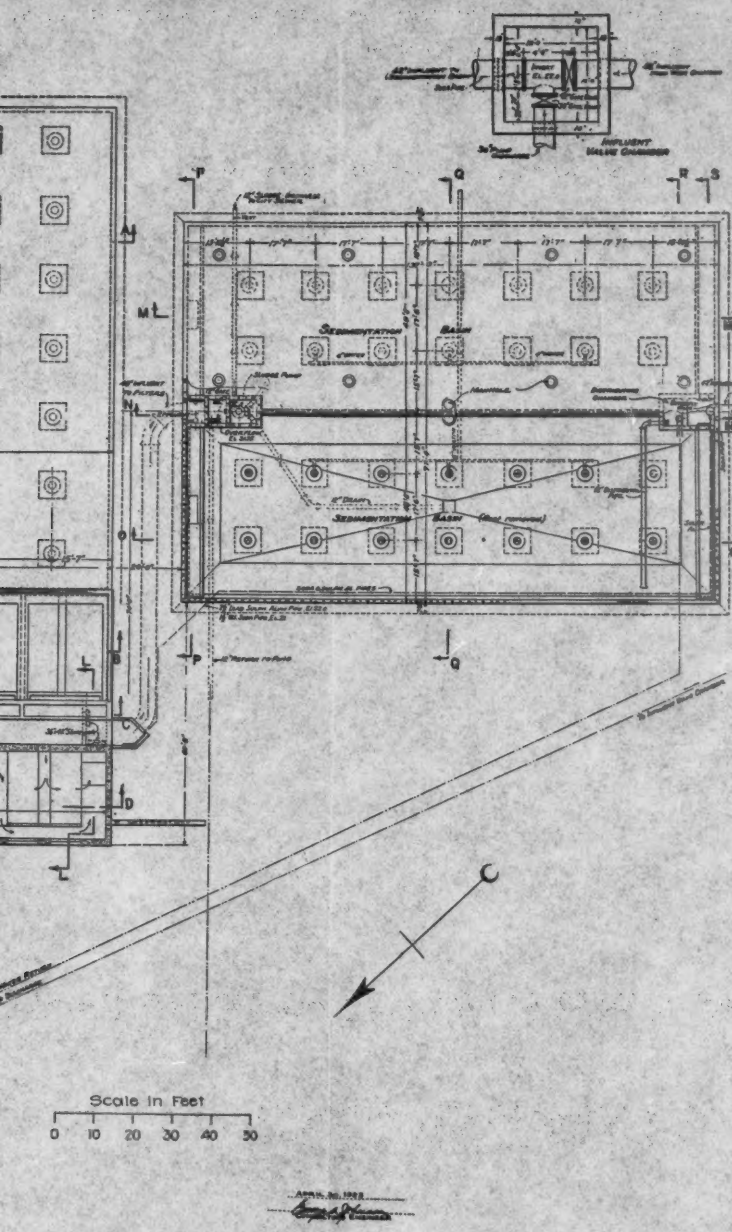
VOL. XXXVII.

JOHNSON

RAPID SAND FILTRATION,

CAMBRIDGE, MASS.

DISCUSSION — STEVENS.



adapt the operation of the filter plant to the main high-service pump which discharges approximately at the rate of 20 mil. gal. per 24 hr., making it necessary ordinarily to deliver the day's supply within a period of 16 hr.

The type of concrete reinforcement adopted for the roof and floor of this basin, and similarly for the sedimentation basin is of particular interest, and a description of it will be included in another discussion covering the methods of reinforcement used in the Cambridge filter plant.

Washing. Wash water is delivered from a steel tank 29 ft. in diameter and 34 ft. high, through a main with valved connections into the effluent pipe of each filter, passes reversely through the collecting system and upward through the filter at a rate of about 15 gal. per sq. ft. per min., loosening the sand and carrying off the accumulated muddy matter.

The dirty water runs through the gutters to the waste compartment at the end of each filter and thence through a drain to the wash-water receiving basin. From this basin the dirty water is returned to the sedimentation basin by pumps which start automatically as soon as the receiving basin begins to fill.

The receiving basin is an unusual feature installed for the purposes of saving water and of aiding coagulation, as has been more fully stated by Colonel Johnson.

The wash-water tank contains enough water for two successive washes and is replenished by small motor-driven pumps one or both of which start automatically with the draft on the tank. A connection with the city force main may also be used to fill the tank in emergency. Wash water delivered by the pumps is measured by a Venturi meter.

Plate II and III show various sections of the filters, clear-water basin, aërator, etc. Plate IV shows various sections of the sedimentation basin.

Plate V shows details of a filter unit and the arrangement of pipe, valves, and other appurtenances.

The collecting system of the filters is worthy of comment. It is known as the Wheeler bottom. It serves to collect and deliver the filtered water, but its more important function is the proper distribution of wash water beneath the filtering material.

It consists of a central duct through the middle of the filter with closely spaced lateral ducts, all formed in concrete.

Each lateral has a series of openings, shaped like inverted pyramids, in which are placed cement balls of varying size, a large one at the bottom, four smaller ones above it, and nine, still smaller, in the top layer. These balls spread out the entering wash water and deliver it gently and evenly into the overlying gravel, thus causing a very uniform upward flow with no tendency for the water to bore through the sand and gravel, and leave unwashed spaces between openings.

Aërator. The aërator consists merely of cast-iron plates studded with short baffles 6 in. long and 4 in. high set diagonally. The plates lie on a slope of 3 ft. on 8 ft. Their total area is 923 sq. ft.

The water flowing down over these plates is thoroughly splashed and turned over so that there results an effective release of carbonic acid and thorough contact with the air with consequent deodorization. Three feet of head is necessarily lost through the operation of the aërator.

Chlorinator. A separate room is provided for chlorinating equipment and storage of chlorine, with no interior connection to the rest of the building except a double door opening to the filter-operating floor. The equipment consists of a Wallace and Tiernan pedestal type chlorinator with accessories.

The chlorine is applied through a rubber tube at the point where the water passes from the aërator to the clear-water basin.

Chemical Equipment. Chemicals are dissolved in concrete tanks provided with motor-driven mixing devices. The dissolving of chemical is accomplished by placing it on a grating in a compartment at the top of the tank and spraying upon it the water used to fill the tank. The alum solution is passed through a small filter and delivered by a little pump to orifice tanks at sufficient elevation to permit gravity flow to the point of application at the entrance to the sedimentation basin. The soda solution is similarly measured through orifice tanks and then forced by a water jet eductor through the delivery pipe.

Ample storage space, with elevator, provides for receiving chemicals in carload lots.

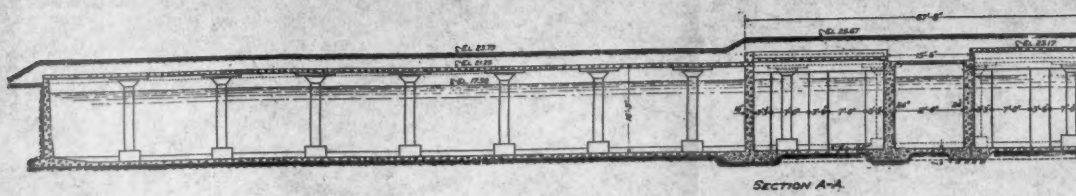
Laboratories. A well-equipped laboratory is an essential factor in a properly-conducted filter plant. Three rooms are provided for this purpose and they have been furnished with complete facilities and the best of apparatus.

The Cambridge filter plant represents the best filter practice and is of high-class construction. The photographs herewith reproduced give a clear idea of the character of the plant. The city of Cambridge is assured of constantly pure water supply and conservation of its past development, all at a reasonable cost, adequate for many years, and capable of extension when more water is required.

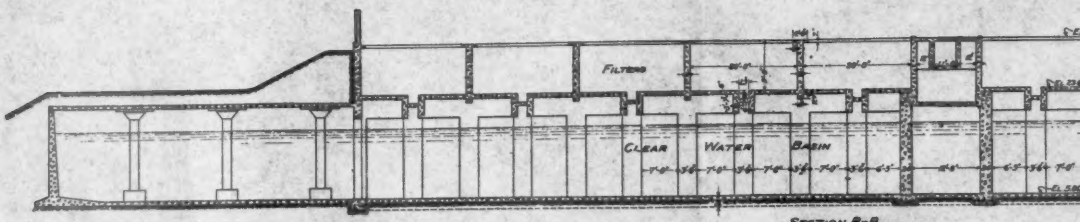
TIMOTHY W. GOOD.* The people of Cambridge are indebted to Col. George A. Johnson for furnishing the Water Board with what is considered by experts to be the finest mechanical filter plant in this country. One must, however, see the plant in operation to appreciate fully his work.

His method of handling the many intricate problems, the rapid completion of the plant, and the wonderful results obtained, have earned for him the everlasting gratitude of the Mayor, Water Board, and the citizens of Cambridge. I regret very much that Mr. Melville C. Whipple, our consulting chemist, is not present, but pressure of work at Harvard University prevented his attending. I will, however, endeavor to give you an idea of the chemical operation as well as the practical operation of the plant.

* Superintendent, Water Works, Cambridge, Mass.



SECTION A-A.



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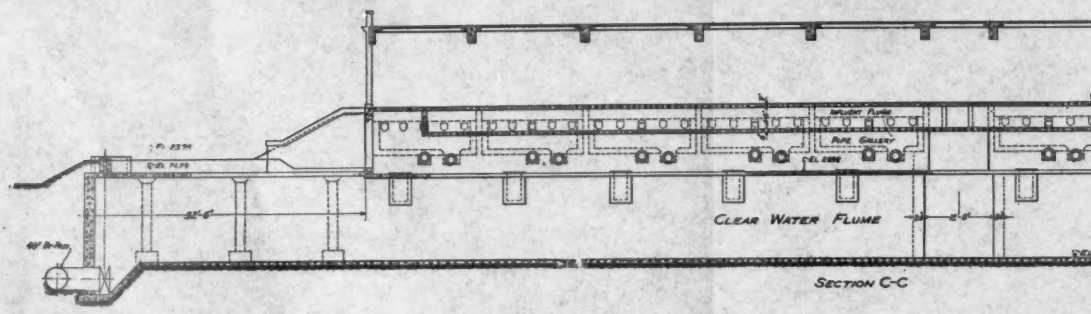
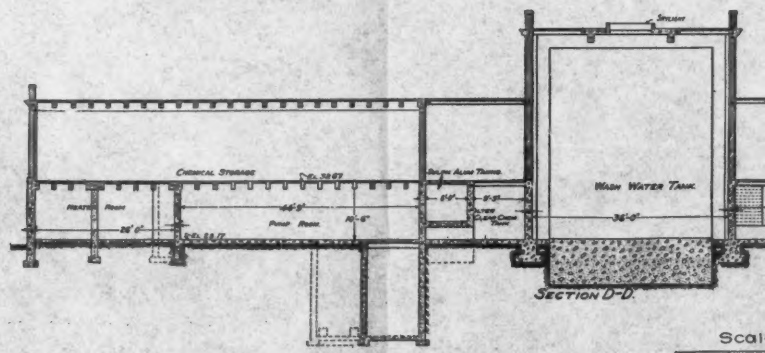


SECTION C-C



SECTION D-D.

Scal

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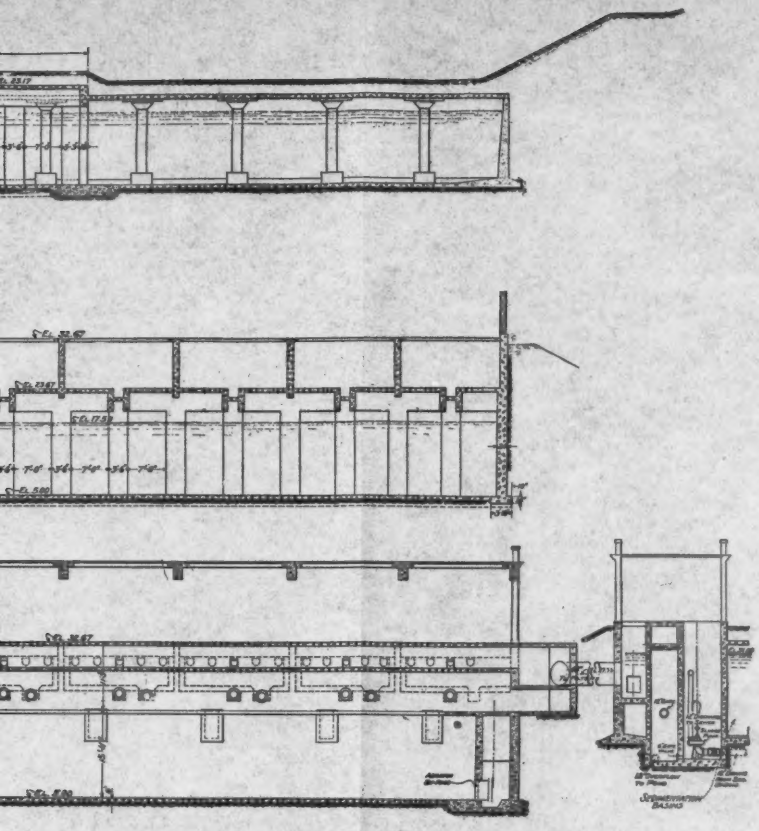
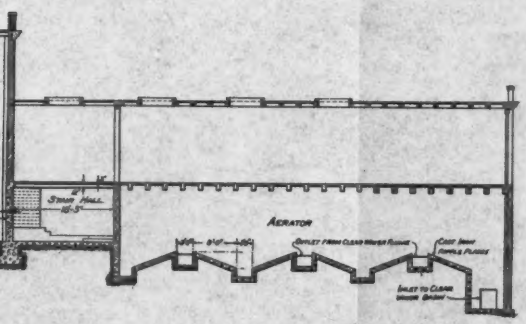
FILTERS, CLEAR-WATER BASIN, ETC. — SECT



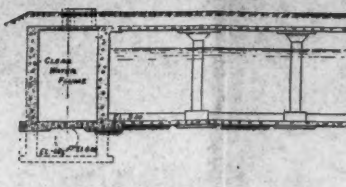


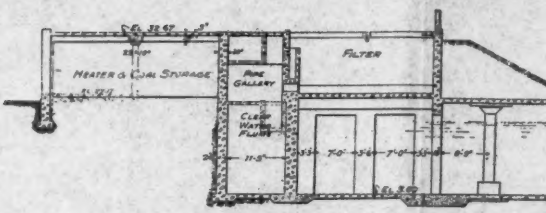
Scale in FEET

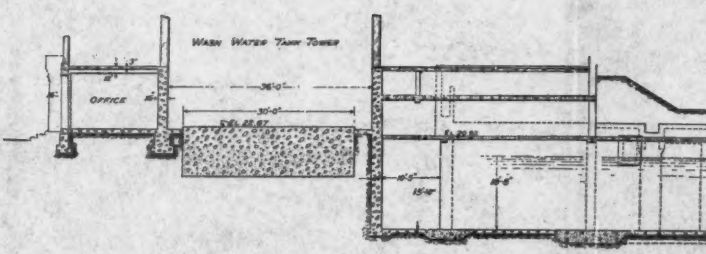
0 10 20 30 40

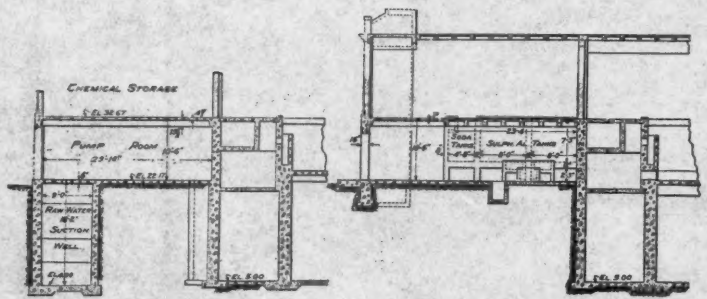
APRIL 20, 1932

ECTIONS.





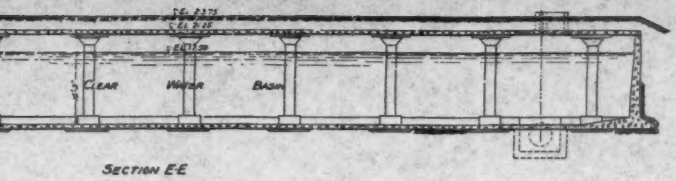




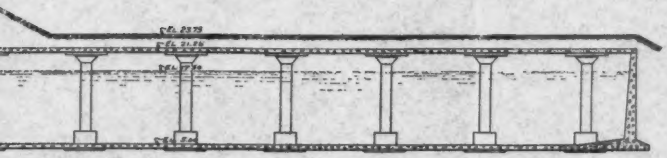
SECTION H-H.

SECTION I-I

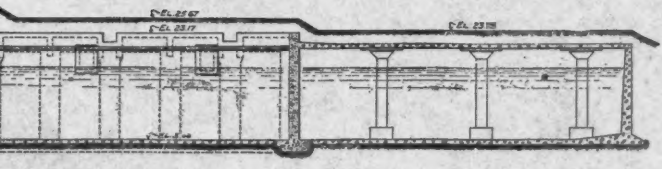
FILTERS, CLEAR-WATER



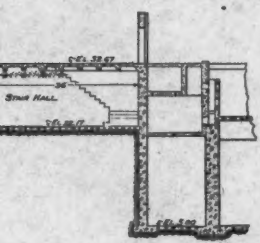
SECTION E-E



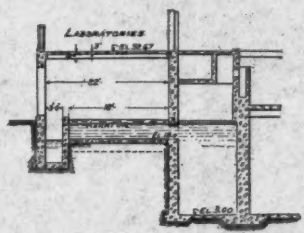
SECTION F-F



SECTION G-G



SECTION J-J.



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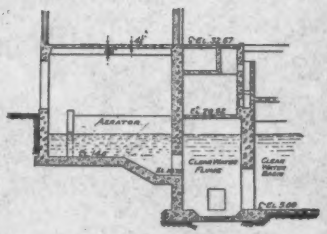


SECTION L-L.

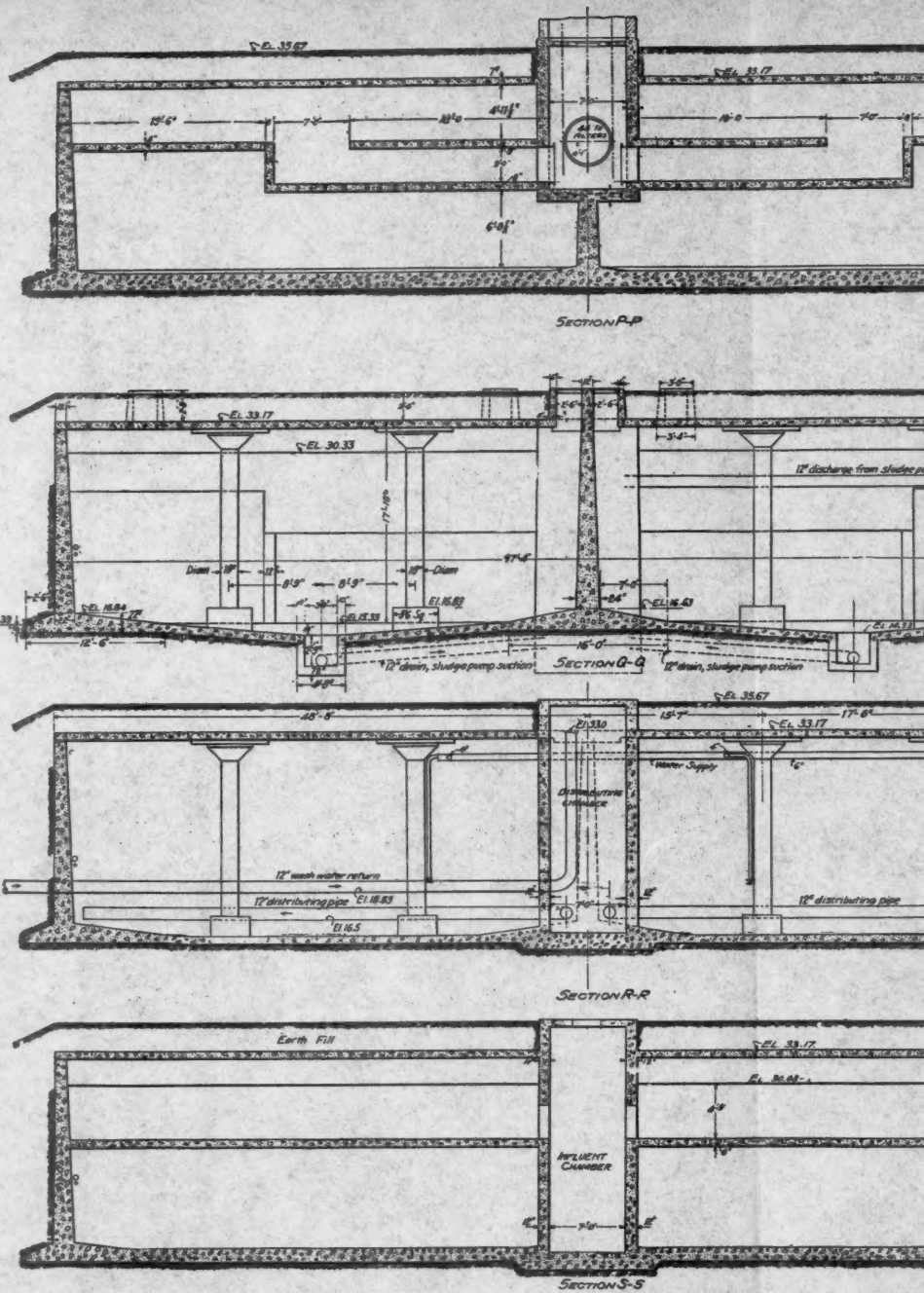
Scale in Feet

0 10 20 30 40

APRIL 24, 1906.

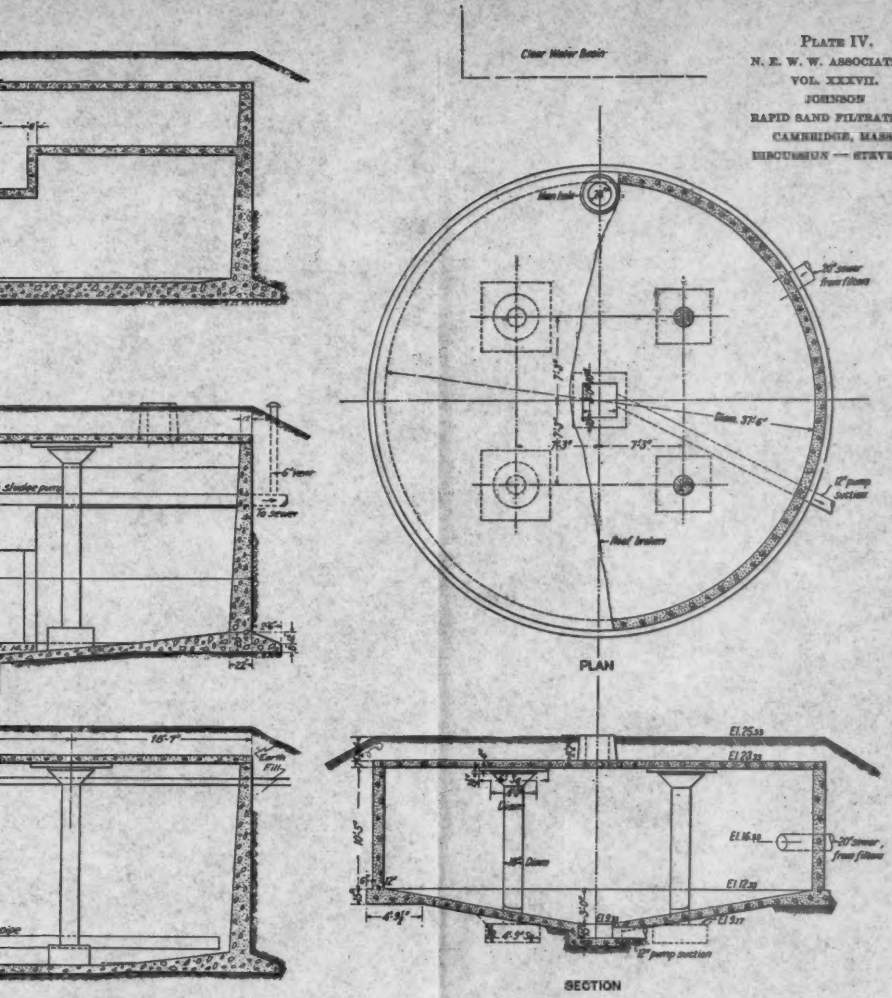
GEORGE A. STEVENS
CHIEF ENGINEER

ATER BASIN, ETC. — SECTIONS.

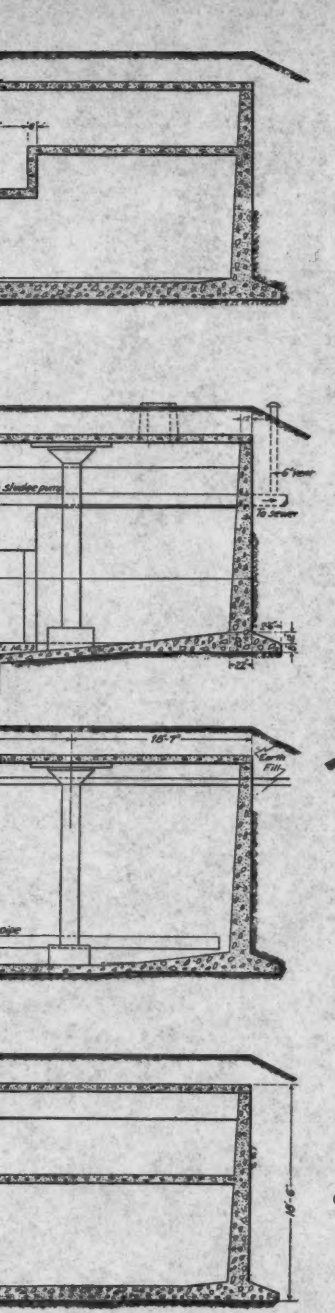


SEDIMENTATION BASIN

SEDIMENTATION BASIN AND WASH-W



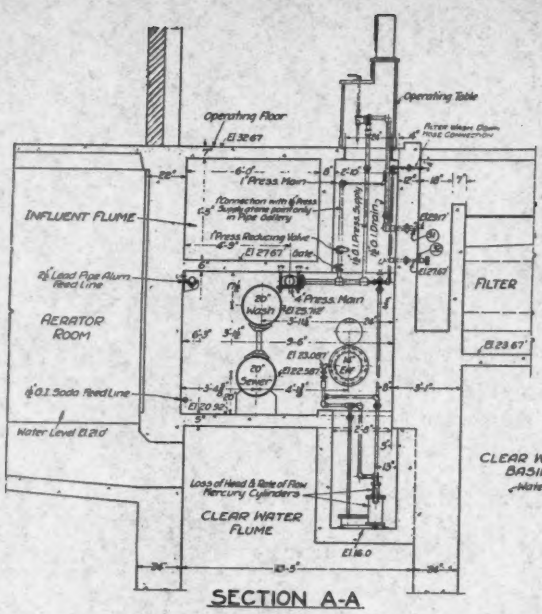
WASH WATER RECEIVING BASIN



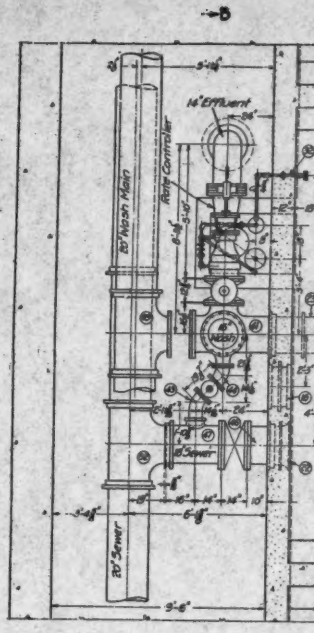
Scale in Feet.

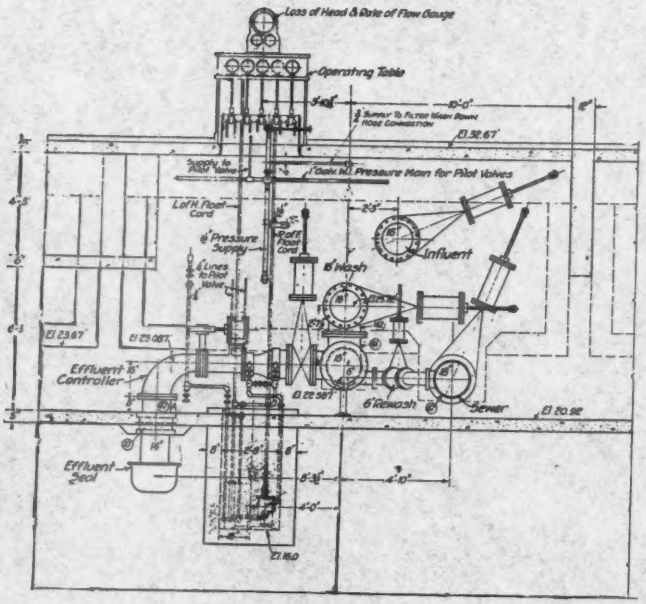
0 5 10 15 20

H-WATER RECEIVING BASIN.

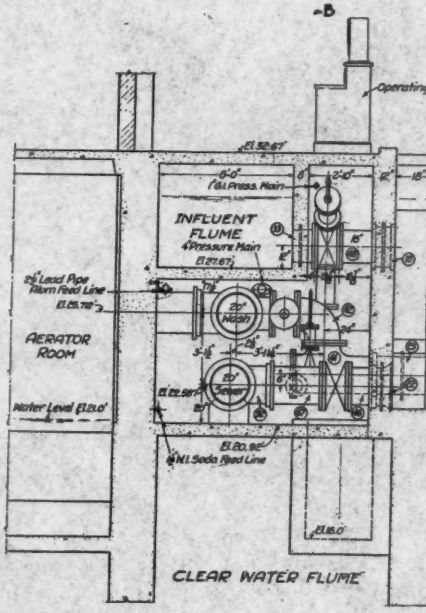


SECTION A-A



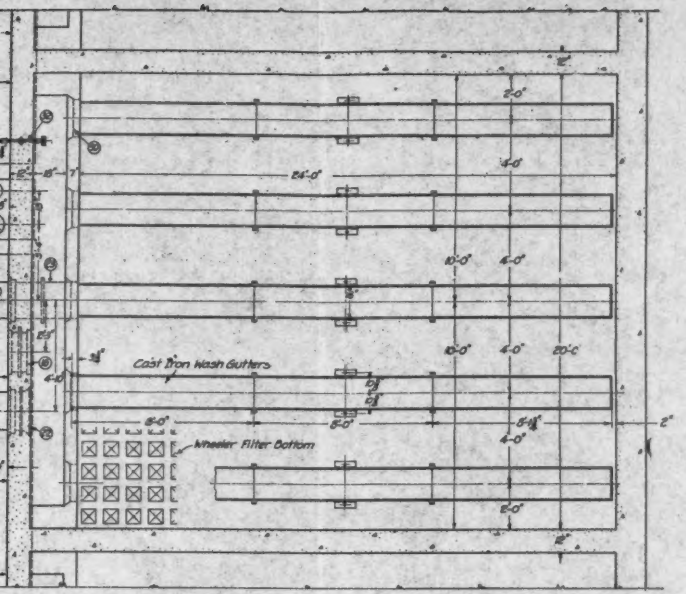


SECTION B-B

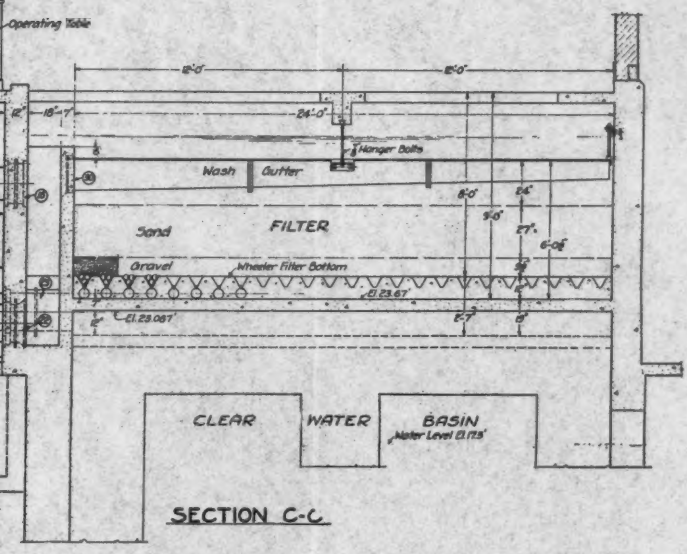


DETAILS OF FILTER UNITS.

PLATE V.
N. E. W. W. ASSOCIATION.
VOL. XXXVII.
JOHNSON
RAPID SAND FILTRATION,
CAMBRIDGE, MASS.
DISCUSSION — STEVENS.



PLAN



SECTION C-C

Scale in Feet

0 2 4 6 8 10

Rapid sand, or, as it is oftentimes called, mechanical filtration, differs from slow sand filtration in three essential particulars. In the first place, water is passed through the sand at a rate some thirty times faster than in slow sand filtration. Second, entirely different means are used for cleaning the sand when the filters become clogged. The flow of water is reversed, the sand put in suspension and the grains rub against each other until they are clean. In the slow sand process the upper layer of sand, usually about one inch, is removed by scraping and the sand is washed in special apparatus. It is not returned to the bed until successive scrapings have greatly reduced the depth of sand. The third essential difference in the two processes arises from the use of a coagulating chemical, which is added to the water before filtration. This removes the largest portion of impurities, both living and inert, in a settling basin, and so makes possible in the rapid method the use of much higher rates of filtration. Coagulating chemicals are not ordinarily employed previous to slow sand filtration.

Description of the Coagulation Process. Coagulation, in water treatment, implies the natural assembling of minute particles of precipitate into relatively large flocs, which incidentally entrain particles of clay, of organic and coloring matter, and of living organisms, such as the bacteria and algæ. The process accomplishes the same result as the addition of white of egg to coffee, which is often added to clarify it. The egg white there coagulates, forming large particles which readily settle. These particles in the process of forming include and drag down the small particles which give the coffee a muddy appearance.

For purposes of water treatment the coagulating substance must be one which will form a coarse precipitate and settle readily. Such a substance is aluminum sulphate, sometimes called filter alum. It has weak acid properties. A solution of this substance is added to the water just before it enters a settling, or sedimentation basin. Being weakly acid, it combines with the alkaline salts naturally present in the water. These are bicarbonates of lime (calcium) and magnesium. The result of this combination is the formation of an insoluble compound, aluminum hydroxide. The latter first forms in very fine particles. These gradually come together to form visible masses of a sticky, coarse nature which settle readily. In the formation and settling, bacteria, algæ, and the minute particles giving rise to color and to a " roily " appearance are caught in the precipitate of aluminum hydroxide and removed from the water. The time required for settlement will vary from two to four hours and this period is obtained by the passage of the treated water through the settling basin. The amount of aluminum sulphate used will vary with the temperature and the quality of the raw water and will probably be between 200 and 215 lb. per mil. gal., that is, between 1.4 and 1.5 grains per gal.

All of the precipitate formed in the basin does not settle out there. Some of it passes on in the water to the filters, where it is caught on the

surface of the sand and aids in building up a mat which greatly increases the efficiency of the filtering process. When this mat becomes so thick that the passage of water is interfered with, the filter has to be washed. The nature of the water, and the matter in suspension, is different from that found in any other part of this country. The floc formed by adding alum is light and of a sticky nature, more especially in warm weather, forming a much denser mat on the top of the filter bed than could be removed by ordinary washing. This we overcame by increasing our rate to 18 gal. per sq. ft. per min. The settling basin must also be cleaned periodically. This is indicated by the time when precipitate is carried out of it to the filters in such quantity that the latter have to be washed too frequently.

The Use of Soda. After treating the raw water with aluminum sulphate, there must always remain an excess of alkaline salts, " alkalinity " as it is called, in order that no aluminum sulphate may be carried into the mains. The amount of natural lime salts may at times be insufficient to assure this. Laboratory examinations will indicate the condition. Then it will be necessary to add artificial alkalinity in an amount equivalent to the deficiency of natural alkalinity. The substance used for the purpose is sodium carbonate, or washing soda, which is introduced to the raw water as a solution. The apparatus for doing this, and for adding the solution of aluminum sulphate, is accurately controlled and the exact amounts are checked by laboratory analyses. Neither of these substances is added in an amount which can be tasted or be harmful. Furthermore, the aluminum sulphate is precipitated from the water, as above described, before it is filtered. It may be necessary to add soda only a few weeks each year and possibly not at all.

Other Substances Formed in the Coagulation Process. When part of the alkaline lime and magnesium salts are neutralized by the aluminum sulphate with the formation of the precipitate of aluminum hydroxide, they are converted into sulphate of lime and magnesium, respectively. These remain in solution. The total hardness is unchanged in amount, but its character is changed.

The reaction of the coagulating process also gives rise to the formation of carbon dioxide, or carbonic acid, the substance which is used to charge soda water. Some of this gas is present in the natural raw water. The amount in the filtered water will be doubled. It is a fact known to chemical science that carbonic acid increases the ability of water to corrode metal pipes. It also promotes the growth of algæ in uncovered reservoirs. For these reasons an aërator has been provided to take out part of the gas, also to remove odors. When water containing carbonic acid and substances causing odors is brought into intimate contact with the air there is a tendency for these to escape from the water. The aërator receives the water after filtration.

The Disinfection of Cambridge Water. Disinfection is primarily

employed for the purpose of destroying disease bacteria which find their way to natural waters. The germs of typhoid fever, cholera, dysentery, and diarrhœa may occur from time to time. They do not multiply but tend to decrease in number. The process also destroys many harmless forms of water bacteria and certain other types which originate from objectionable sources but are not disease-producing forms. They are indicators of possible danger in that disease bacteria may accompany them. Such a type is Bacterium coli.

A large percentage of all forms of bacteria are removed by the process of coagulation and settling. The number is further decreased by filtration. To guard against fluctuations or irregularities in the quality of the filtered water, disinfection is employed as a finishing process before the water leaves the plant. It is accomplished by the addition of a solution of chlorine gas. The amount required does not exceed 3 lb. of chlorine per mil. gal., and is very accurately measured and controlled by the Wallace and Tiernan Vacuum Feed Chlorinator. Of this amount practically none can reach the mains of the city because the chlorine is neutralized by the bacteria and by the small amount of organic matter in the water. Ordinarily no chlorine will be found by test 30 min. after it is added. Chlorine has never been considered injurious in the amounts in which it is used in water disinfection. It is intended that no chlorine will be present in the water as it comes to the consumer's tap.

The water will not be sterile after chlorine treatment. There is nothing to be gained in an attempt to destroy all the common, harmless species of bacteria. What the processes of coagulation, filtration, and disinfection are designed to accomplish is the elimination of "objectionable aliens," such as Bacterium coli. If these are destroyed, we may then assume that specific disease organisms have also been removed.

The filter plant was placed in operation April 14, of this year, and our aim was to give the maximum of efficiency with a minimum of cost, both of which I am proud to say we have accomplished. We are operating with a chemist, 5 filter operators and 1 electrician, making a total of 7 men to operate the plant, each man working 8 hr. per shift, changing every 5 days. We filter approximately 13 mil. gal. of water every 24 hr., while our pumping is completed within a period of 15 hr. The return of wash water is not a detriment to good coagulation as the efficiency of coagulation basin is from 60 per cent to 70 per cent. While our gravity supply delivers 12 to 13 mil. gal. per day, there are times when our auxillary pumps lift from 1 to 4 mil. gal. from Fresh Pond, thus insuring capacity at all times. I might state here that returning the wash water to the sedimentation basin has conserved 87 mil. gal. of water that would otherwise have passed into the sewer. We have found that the best sand for the filter beds could be secured a short distance from Cambridge, namely Newburyport Plum Island sand, and the best results in length of run, removal of bacteria, color and turbidity were obtained from filter beds having effective size of

0.40 to 0.42 mm. The color of our raw water averages 30 parts per million, the turbidity 3 parts per million. After the water is filtered, color and turbidity are practically 0. Our removal of bacteria is usually 100 per cent. With iron removed to within .05 parts per million, with all gases, growth, and color entirely removed, we take great pride in delivering water to the consumer practically perfect for drinking, household, and industrial purposes at a cost of 10 cents per 100 cu. ft. Our operating costs at plant are not in excess of $8.00 per mil. gal. delivered at pumping station.

Now, gentlemen, in behalf of the Mayor and the Water Board of Cambridge, I want to extend to the President and members of your Association an invitation to hold one of your fall meetings, as guests of the city of Cambridge, at the filter plant, where we assure you that every courtesy will be shown you, and we will give you an opportunity to view what we consider one of the finest filter plants in the world, and one of the best examples of a municipal building that stands in the United States.

EDWARD SMULSKI.* This discussion supplements Colonel Johnson's paper so far as structural features of the plant are concerned.

Roof and Bottom of Basins. The roof and bottom of the sedimentation basin, wash-water basin and of a major part of the fresh-water basin are of reinforced-concrete flat-slab construction. The arrangement of panels and the spacing of columns are evident from the plan of the clear-water and sedimentation basins shown in Plate I.

The columns are spaced 17 ft. 6 in. on centers. The construction of the roof consists of a slab supported by columns with enlarged capital. At the column capital the slab is thickened by the introduction of a square drop panel. The bottom of the basin is of similar design. The capital however is replaced by a concrete block placed above the slab. The drop panel is placed under the slab to simplify the construction and to avoid form work. The general features of the design may be seen in the sections through the basins. Section FF in Plate III shows a section through the clear-water basin and Plate IV shows sections through the sedimentation basin.

The roof is designed to carry in addition to the weight of the slab a load of 340 lb. per sq. ft. The bottom is designed for an upward pressure equal to the unit load on the roof.

An interesting feature of the design is the flat-slab reinforcement. This is arranged according to the S. M. I. or Smulski system, which is distinguished by the use of a combination of rings and radial bars. By this arrangement considerable economy in steel is obtained. In ordinary cases at least 25 per cent of steel is saved without reducing the strength of the construction.

Figure 4 shows the arrangement of steel in detail and represents an interior and exterior panel of the roof. The steel indicated by heavy lines is placed near the top of the slab while the steel shown by light lines is near the bottom.

* Consulting Engineer, New York City.

In general the reinforcement consists of four types of units designated by letters A, B, C, and T. Units A and B are placed near the bottom of the slab and serve to resist the positive bending moment. Units C and T are placed near the top of the slab and resist the negative bending moment.

The composition of the various units is evident from the illustration. Unit A, which is placed between columns, consists of 4 concentric rings and 3 bars, one of which is bent up to the top of the slab at both ends and carried across the column into the adjoining panel. Unit B, placed in the

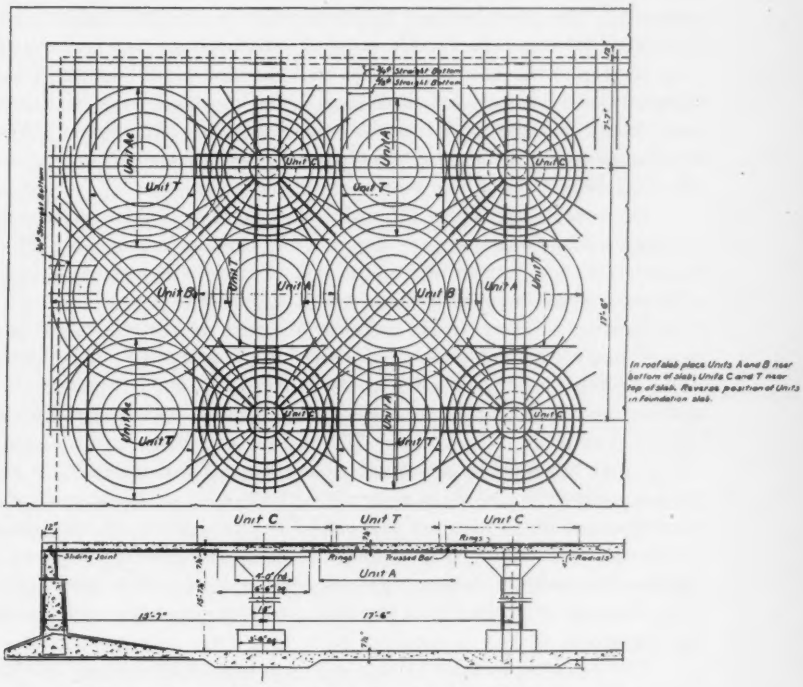

Unit A
Unit B
Unit C
Unit T
Rings
Trussed Bar
Radials
Sliding Joint
In roof slab place Units A and B near bottom of slab; Units C and T near top of slab. Reverse position of Units in Foundation slab.

FIG. 4. TYPICAL REINFORCEMENT OF ROOF OF BASINS.

center of the panel, consists of 6 concentric rings and diagonal bars. A part of the diagonals are bent up and carried to the column where they are anchored.

Unit C, placed at the column, consists of rings and radials. Some of the radials do not extend across the column but are hooked to a ring placed within the column head. The negative reinforcement at the column is supplemented by the bent bars from Units A and B.

Unit T, placed across Unit A, consists of straight bars.

It should be noted that the rings of the various units overlap, forming a continuous mat of reinforcement. At the column the large concentration

of small bars, usual in other systems, is avoided. The bars there are far apart so that the concrete can be poured without difficulty.

Action of S. M. I. Reinforcement. The action of the reinforcement may be understood by considering the deflection of the slab. When loaded, the slab in a general way assumes the shape of an umbrella at the column and the shape of a saucer in the central part. The umbrella-shaped part of the slab acts like a circumferential cantilever loaded over its area and also along its circumference by the load transmitted to it by the rest of the slab. The circumferential cantilever is subjected to negative bending moment. The particles near the upper part of the slab elongate and are therefore subjected to tensile stresses. Reinforcement must be placed near the top of the slab. It is clear that the stresses will act on all sides in circumferential and radial directions. The most effective reinforcement accordingly is placed in circumferential and radial directions. The rings act like hoops on the barrel. They prevent the concrete within from spreading and thereby keep the construction intact.

The central portion of the slab, which assumes the shape of a saucer is subjected to tensile stresses at the lower portion of the slab. The steel is placed at the bottom and the action of rings is similar to that at the column and the hooping action is equally effective.

Bending of Rings. The bending of rings is a very simple process. An ordinary tire bender may be used for the purpose. This consists of three rollers, two of which are at the bottom and one at the top. One of the bottom rollers and the top roller are connected by gears with the driving shaft. The other roller is free. Its position with respect to the other two rollers may be varied by moving it up or down. The position of the free roller determines the size of the ring. The tire bender is usually run by power.

The bars to be bent are first cut to lengths equal to the circumference of the ring plus the length of the lap. The bars are passed through the bender, the ends are then brought together and properly lapped and wired. This bending is simpler than the two double bends required in rectilinear arrangement.

Flat Slab vs. *Groined Arches.* The principal advantage of the reinforced-concrete-slab type over groined arches is that the reinforced-concrete construction is stable under all conditions. The required dimensions for the roof and bottom can be computed with sufficient accuracy. The factor of safety depends upon the assumption made by the designer and he can get as strong a structure as he desires without waste of material. Each part of the slab depends for its stability only upon the construction immediately adjacent. The weakness in any part is confined to the part in question. This means that if for any reason a portion of the slab should fail, such failure will not cause the collapse of the whole structure.

With groined-arch construction the stability of the arches does not depend upon the strength of the arches but upon the strength of the walls. If the walls yield the whole structure fails. No section is stable by itself.

One section supports the other. Failure of one arch causes failure of the whole row of arches. There is no rational method of designing the arches. The designer cannot be sure of the factor of safety. Even excessive thickness of the arches will not insure safety of the construction because yielding of walls would destroy the arches irrespective of the dimensions.

Walls. The side walls of the basins are of the inverted T type. The roof rests on the wall but it is not connected with it. A sliding joint is provided between the wall and the roof so as to relieve the heavy stresses in the wall that otherwise would be caused by expansion and contraction of the roof. The base of the wall, however, is built monolithically with the bottom of the basin.

The walls are designed for two conditions. First for earth pressure considering the basin empty; Second for water pressure with the basin full. In the latter case it is assumed that one-half of the water pressure is resisted by the passive earth pressure. It was not considered advisable to assume that the earth would resist the full water pressure.

The design of the wall and the arrangement of reinforcement are indicated in Figure 4.

Filters. Section BB in Plate II shows the filters, which are supported over and along one side of the clear-water basin. There are ten filters placed in a row, in two groups of five each. Each filter is in the form of a box enclosed on four sides and on the bottom and supported over the clear-water basin. The bottom of the filter forms a part of the roof of the basin.

Figure 5 shows details of the filter construction.

The bottom of the filters is of beam and slab design. The arrangement of beams is evident from the cross section. Beams and slabs are designed to carry the heavy filter load including water.

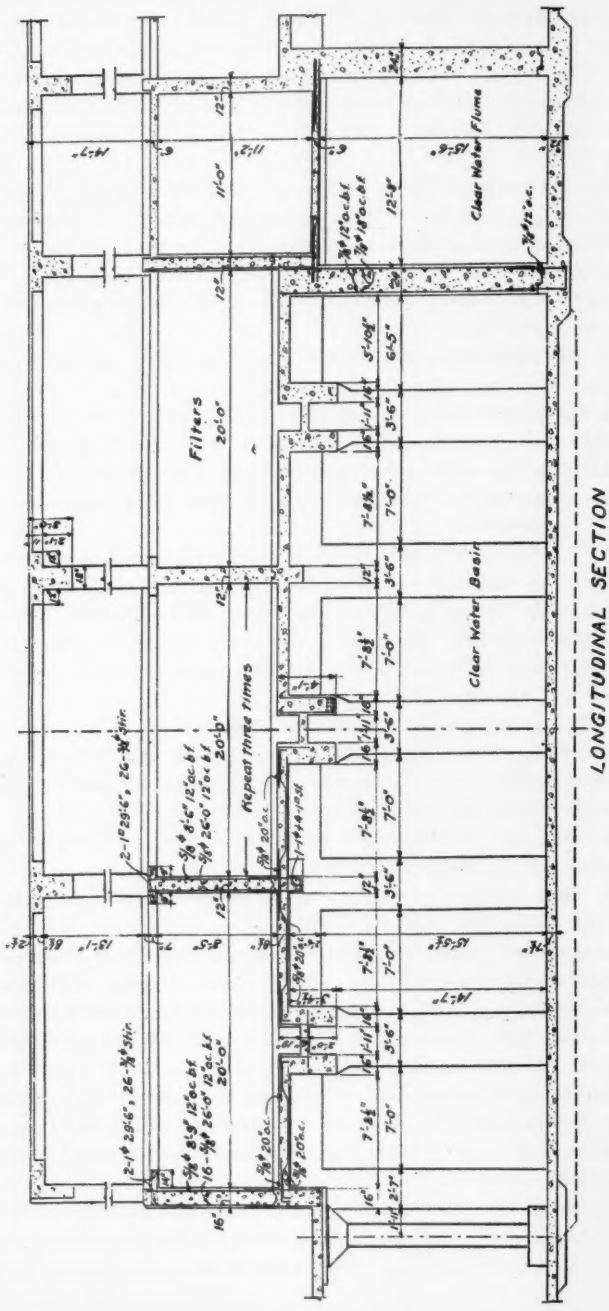
The walls of the boxes are designed to resist full water pressure, considering the adjoining filter empty.

The filter bottom rests on special columns in the clear-water basin and on the wall in the clear-water flume.

The pressure under the footings carrying the filters is considerably more than under other footings of the basin. It was anticipated that there would be more settlement under the filter than elsewhere, and there is provision in the reinforcement of the roof and the bottom for the reverse bending due to such settlement.

Temperature Reinforcement. To make the structure as water-tight as possible, all parts of the structure are provided with proper amount of temperature steel, and cracking at the juncture of the various members is avoided by proper negative moment reinforcement.

Superstructure. The superstructure floors and roof are of long span joist construction. This consists of narrow joists spaced 27 in. in the clear and connected by a thin slab. This construction was obtained by the use



LONGITUDINAL SECTION

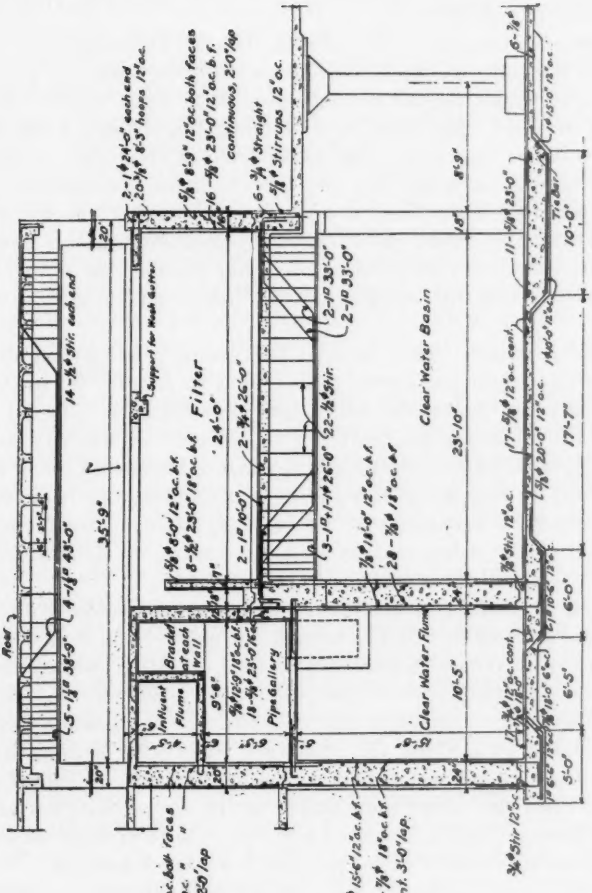


FIG. 5. REINFORCEMENT OF FILTERS.

of steel forms or pans. Figure 5 shows the arrangement of the joists in the roof over the filters.

The joists are carried by long span girders. The design of the girder over the filters is shown in elevation and section. The T flange of the beam is obtained by making the slab adjacent to the beams of a thickness equal to the depth of the joists.

MR. LEWIS I. BIRDSALL.* I would like to ask Colonel Johnson if he considered, in returning the wash water to the receiving basin, the putting in of a weir and permitting the heavier solids of the wash water to settle out, weiring over the clear water and pumping that back? I ask that question because we considered it at Minneapolis in connection with the plant there, having taken up with the City Engineer the building of a wash-water receiving basin where it would be very easy to run the wash water. We, however, would have had to separate our sanitary sewage from the wash water. I take it for granted that you did that in this case in designing it, so that the sewage from the toilets did not go into that effluent.

COLONEL JOHNSON. That is so. The sanitary sewage from the toilets in the filter plant goes directly into a near-by sewer. We made no attempt to settle out the heavier solids from the wash water before it was returned to the sedimentation basin, for the reason that the city sewer, into which the wash water is discharged, is restricted in size and somewhat flat in spots and we were afraid of deposits. Consequently, we endeavored to keep all suspended matters in the return wash water in suspension and took them all to the sedimentation basin because we thought we could take care of them better there than we could otherwise.

MR. W. C. HAWLEY.† I was interested in this proposition of the use of the returned wash water. When we built our plant — the Pennsylvania Water Company, in Wilkes-Barre, Penn., in 1909 or 1910 — we introduced the same feature there. However, the wash water is allowed to settle for a period of about five or six hours, and then returned to the sedimentation basin. We found by analysis that the wash water after settling was a better water than the raw water from the pumping station. I figured that after we had lifted that water some 600 ft. in the air we could not afford to let it run downhill again, and we have been able to operate our plant with a use of about one-tenth of one per cent of water for washing.

MR. F. H. HAYES.‡ May I ask, Colonel Johnson, why, in the first starting of the filter at Cambridge, the water was so blue?

COLONEL JOHNSON. Why, I think it might have seemed blue because it previously had been so yellow. I don't know of any other explanation.

MR. HAYES. I might say that what brought it to our attention was that in our washbowl we noticed, when you first put the filter plant in use,

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* Of the General Chemical Company, Chicago, Ill.

† Chief Engineer, Pennsylvania Water Company, Wilkinsburg, Penn.

‡ Of Hayes Pump and Machinery Company, Boston, Mass.

before there was any notice of its being in operation, there was a blue streak, and until about three or four weeks ago it was there. Now it is getting to be a little brown.

COLONEL JOHNSON. I am sure I do not know. The reason, perhaps, it is getting a little brown now, is because of some changes at the pumping station which have necessitated the closing down temporarily of the filter plant, until the necessary changes are made.

MR. CALEB M. SAVILLE.* Colonel Johnson has courteously referred several times to our good-natured discussion of the merits of slow and rapid sand filtration plants as exemplified in those recently constructed at Hartford, Conn., and Cambridge, Mass.

At the outset it may, perhaps, be pertinent to reiterate what is almost axiomatic in water-supply filtration work, viz., that while first cost of the slow sand type of filter is usually in excess of that of the rapid sand type, yet when it comes to operation, with our New England waters at any rate, the capitalized cost of operation and maintenance of the latter, including labor, materials and power, compared on the basis of unit volume delivered, often more than makes up for the lower first cost of the rapid plant, including both interest and depreciation.

Colonel Johnson's paper, including those of his colleagues, is one of the most complete descriptions of an up-to-date rapid sand filtration plant that it has been my privilege to listen to, and it is to such papers as his that this Association owes the enviable place it holds in water-works affairs and places the contents of its journals in the forefront of practical water-works literature.

The paper is a very clear exposition of what has been done in Cambridge to give the people a really good water supply. I have had the privilege of inspecting the Cambridge filtration plant, and very gladly testify to the excellent appearance of the buildings, both inside and out, to its apparent convenience for operation, and its general businesslike atmosphere. The buildings are attractive without being ornate, and in keeping both with their surroundings and their place in the municipal planning of a city of the importance of Cambridge.

At this time it is well to pause for remark that engineers too often overlook the esthetic in the search for the utilitarian. The great example for all time of the careful blending of the architecturally beautiful with efficiency in use and operation is found par excellence in the development of the Metropolitan Water Works under that master of water-works engineering, the late Mr. Frederic P. Stearns. The nearby imposing buildings of this system for housing pumps and other appurtenances at Chestnut Hill Reservoir forbids any rough building in this vicinity for similar purposes just suitable for shedding the snow and rain. The taxpayers to-day are demanding that something be shown above ground for the money

* Chief Engineer, Board of Water Commissioners, Hartford, Conn.

expended, and with present human nature no amount of agreeable sanitary water manufactured out of sight can quite compare with that which comes, as it were, in an attractive package.

Right here, however, is where perhaps Colonel Johnson and I part company, or maybe each of us goes to his own side of the same street for a little while without the least prejudice to each other's viewpoint in looking for the best. The whole nub of the matter is: What is the best method of filtration for individual conditions? What may have been the governing factors in choosing rapid sand filtration for Cambridge I do not know, but for Hartford I can say that there was much difference of opinion at the outset as to the best method of filtration for Hartford water, and while the advice of some of the best known experts in this line in the country was sought, even that was divided between rapid and slow sand methods. However, from the operating conditions that have existed since the plant was put in commission, I am very frank to say that I am glad that the choice of slow sand filtration was made, and if the question was now to be decided with past experience I should be more confident than before that the slow sand type of filtration was the proper one for Hartford's water.

The matter of discussion which Colonel Johnson has referred to was really brought upon him by himself. He took occasion some time ago to write an article in one of the scientific papers which I saw giving some figures of the cost of the Cambridge work. Apparently he gave them in a tentative way — did not go into details, but just some rough approximations. I took them for what they said, and made comparisons, and since he has been permitted to revise his figures perhaps I also may revise mine at some time.

The two plants, the Hartford slow sand plant and the Cambridge rapid sand plant, are interesting as having both been built at about the same time and under similar conditions of labor and material costs. Otherwise from that there are some things about both plants which make it really impracticable to compare them fully. For instance, Cambridge has a reservoir storage capacity of something like 2 500 000 000 gal. in round numbers. Hartford has a storage in the neighborhood of 10 000 000. There is a capacity in one of its new reservoirs of 8 000 000 000 gal., which can be called on for decolorization by storage, and 2 000 000 000 more are in other reservoirs — in three other reservoirs. If at any time the large reservoir gets into shape from algæ growth, or something of that kind, so that it is not easily handled with slow sand filters, it is a very simple matter to turn to the other reservoirs and use one or all while the others are being put in condition.

Another thing Colonel Johnson spoke of was a maximum color in the neighborhood of 50, with an average of perhaps 25. Hartford's color has run in the neighborhood of 22 or 23 average for raw water, but has never gone much above 32 or possibly 33. With present reservoir operations it is possible to get raw water about all of the time of color seldom exceeding 25 and deliver a water of color of 17 or less.

Hartford has raw water of excellent sanitary quality to start with, long storage and sparsely inhabited watersheds, making the question of a safe water for delivery of less importance in filtration than might otherwise be the case, and so making filtration rates of 5 and 6 mil. gal. per day per acre permissible.

The hardness of the Hartford water is very much less than that of the Cambridge water, making the slow sand filter perhaps a simpler process here than the other. With these things in mind it is not possible to say that Hartford has a better filter than Cambridge, or that Cambridge has a better filter than Hartford. There are certain conditions, of course, we all know, where there is nothing but a rapid sand filter that will work; it is impracticable to work anything else. There are other conditions where either slow or rapid sand filters can be used. It is a question of judgment. In still other places some of us think that the slow sand filter has advantages that the other does not.

The question perhaps comes down to, "what is a satisfactory color to deliver to consumers?" If we must have zero, or very close to zero — 5 or 8, perhaps all of the time — that is one thing, and only rapid sand filters can be used. If our people are satisfied with colors that will range not over 18, and for most of the time will go about 12 or 14, that is another matter. So taking it all together, I think it is really a question of the engineer's judgment, tempered with what the community desires, and after all public opinion is a good thing to heed, provided no irreparable harm is done or violation of principle is occasioned.

Mr. Frank A. Marston.* I have been much interested in listening to Colonel Johnson's paper and those that followed it, particularly as I have had the pleasure of examining the plant.

There are a number of features about the plant which interested me. One in particular was the use of a Venturi meter on the main wash-water line to control the flow of wash water. Plants have been built in which the reserve pressure of wash water has been such that a careless operator could open the wash-water valve too quickly or too far and seriously disturb the filter under-drainage system thereby. This has been the case not only with the Wheeler type of filter bottom but also with the more common form of pipe strainer and gravel bottom as well as others. The use of a Venturi meter for this purpose is more novel than the common method of putting a stop on the hydraulic piston rod of the wash-water valve so that it cannot be opened too far. The Venturi meter is easily adjustable and should be reliable.

Aside from the description of the filter plant, there is a point mentioned by Mr. Smulski in his discussion upon which there are grounds for a difference of opinion. This is in regard to the relative merits of the use of reinforced-concrete reservoir coverings as against the groined-arch

* Of Metcalf & Eddy, Boston, Mass.

covering. It makes some difference which part of the country the work is in as to the economy of one type of construction as against the other. For instance, a few years ago bids were received by the city of Dayton, Ohio, on a 10 mil. gal. distributing reservoir in which two types of construction were provided, — one, a flat-slab type, of which the Smulski system is an example, and the second a groined arch, which is more common to us here in New England than it is to those in the Middle West. In that case the only bidders were building contractors who were very familiar with flat-slab construction but had had little if any experience with groined-arch construction, and who had in their store yards large numbers of forms suitable for flat-slab construction. They may, also, have been prejudiced by the experience in Cleveland with groined-arch construction, which experience I believe was no discredit to the groined arch but was due to particular conditions encountered. The bids received showed a substantial advantage in the use of the flat slab over the groined arch. The reservoir was built with a roof of flat-slab construction and a floor of the inverted groined-arch type.

Another case: For the filtration plant of the East Chicago and Indiana Harbor Water Co., bids were received for the clear-water and sedimentation basins in the two types of construction, — flat slab and groined arch. The bid for the groined-arch construction was so little in advance of the flat-slab construction that it was accepted, and the groined-arch construction was used for both the roof and the floor.

The groined-arch construction has some advantages if the difference in cost is not too great. In some plants the cost of the groined arch has been low enough so that it probably was comparable with that of the flat-slab construction. The groined arch does not depend upon steel for its strength, and in building a long-lived structure I believe there is something to be said in favor of a structure which does not depend upon the life of steel but which depends upon arch action for its stability and the permanence of concrete for its life.

We have ample precedent to show that the groined arch is a stable, long-lived structure. This does not discredit reinforced concrete. Metcalf & Eddy in the design of the East Chicago plant, used flat-slab construction for the chemical house floors and, incidentally, used the Smulski system of reinforcement.

Another interesting feature of the Smulski system, perhaps of less interest to water-works men, is the method of computing the reinforcing. Mr. Smulski, if I remember correctly, in his discussion said there was no rational method of figuring a groined arch. I think it may be questioned whether there is any more rational method of figuring the Smulski system of reinforcing. Both can be designed satisfactorily to meet the requirements of a reservoir roof. There are engineers who will not give credit to the radial bars in the Smulski system, but this is a debatable question. In the design of the Smulski system which we used on the East Chicago plant, we did use the radial bars.

MR. SMULSKI. As evident from Mr. Marston's discussion, we agree fairly well that flat-slab construction is generally cheaper than groined-arch construction. He cites two cases in which competitive figures were taken for both types and in both cases the flat-slab construction proved to be cheaper. This comparison was based on ordinary flat-slab design; the difference would have been still larger if the Smulski system had been used in the comparison.

Mr. Marston and I differ as to whether the groined arch or the flat slab should receive preference in case of close figures. Mr. Marston is in favor of groined arches because in his opinion it is a long-lived construction. I contend that reinforced concrete should receive preference. The question of longer life for groined arches is fairly doubtful. From the experience thus far it would seem that reinforced-concrete structures are equally permanent, at least for all practical purposes. Against the doubtful advantage of longer life there are the actual disadvantages enumerated in my discussion.

I agree with Mr. Marston that a number of successful groined arches have been built. But it cannot be contradicted that the groined arch is not stable by itself and that it depends upon the outside walls and the stability of the earth support for its strength. The designer does not always know what conditions will be found in the field. He figures on unyielding supports. If his guess is right and no accident happens to any intermediate arches during construction his structure is safe and will last indefinitely. Otherwise his structure tumbles like the Cleveland basin and the Madrid reservoir. These two are cited because they are most widely known. Nobody can deny that if reinforced concrete had been used in these cases failure would either have been averted or localized.

Mr. Marston states that there is no more rational method of figuring the Smulski system than that of figuring groined arches. I am sure that Mr. Marston would have difficulty in upholding this contention. The Smulski system is designed according to the regular flat-slab formulas. By means of these it is possible to provide slabs of a known factor of safety for any length of the span and any desired loading. Numerous tests prove that the formulas give the required factor of safety. If there is any such formula for groined arches, based on equally sound theory to that applied in the case of flat slabs and as thoroughly proved by tests and experiments, I do not know about it.

Mr. Marston also calls attention to the fact that "there are engineers who will not give credit to the radial bars in the Smulski system." Very likely this is true. I will even go farther and admit that there are engineers who for reasons best known to themselves do not give credit to the whole arrangement of the Smulski reinforcement. Since, however, the profession as a whole accepts the obvious fact that the system performs the work for which it is designed, and since in all our tests the radial bars are treated by the loads with proper respect and extensometer readings show

that they resist their share of the stresses, the utility of the radial bars is clearly indicated.

COLONEL JOHNSON. The more pertinent points indicated by those who were good enough to discuss the author's paper are those raised by Messrs. Saville and Marston. The author desires not to overlook any of the discussions that were presented because he appreciates in the fullest degree the courtesies advanced by those who took exception to or commended the work under discussion.

Mr. Marston's commentary on the control of the flow of wash water seems to imply, unintentionally no doubt, that the Wheeler filter bottom is more subject than other types to derangement resulting from an excessively high rate of washing. This is not the fact. The distribution of the entering wash water is more uniform with the Wheeler bottom than with any other type, and this fact alone minimizes the possibility of disturbing the relative arrangement of the various sizes of gravel. No rate of washing which permits the sand to remain in the filter at all will cause derangement with the Wheeler bottom.

Mr. Saville intimates that he and the author may in all possibility part company on questions of methods of water filtration and cost. The author was a member of the Board of Experts employed by the city of Hartford, in whose name Mr. Saville now operates, in connection with their water-supply problem. The author gave them advice relative to the most efficient and economical procedure to follow in Hartford's problem; but Mr. Saville and his supporters were stronger than those of us who make a specialty of this business, and their judgment prevailed.

The question of cost relative to the construction cost of the Cambridge Rapid Sand Filter Plant and the Hartford Slow Sand Filter Plant are exceedingly pertinent at this moment. Mr. Saville had made, prior to the Burlington meeting, a distinct point that the cost of the Hartford works was lower per unit of filtering capacity than those at Cambridge.

Mr. Saville in his discussion has courteously referred to this intimate controversy in ways characteristic and kind of him. Nevertheless, the speaker must, in support of his own position, state that he believes Mr. Saville is thoroughly wrong in the attitude that he has taken. He desires to say that while holding the highest admiration for Mr. Saville as a man, he still has grave doubts about his judgment on slow and rapid sand filtration problems in the New England States.

The author has read very carefully Mr. Saville's detailed remarks explanatory of the reasons why Hartford installed a slow sand filter plant; and even though he thinks so much personally of Mr. Saville, he cannot subscribe to the salient arguments presented him.

HYDRANT CONNECTIONS FOR FIRE ENGINES.

BY FRANK A. MARSTON.*

[*Read September 20, 1923.*]

Fire hydrants should be designed and installed to give the greatest possible service in fighting fires, consistent with reasonable costs of installation and maintenance, and with due regard for the integrity of the water-works system.

The waterways in hydrants should be of sufficient size to prevent material losses in water pressure due to friction, velocity head, and other causes.

For the purpose of connecting hose lines direct to the hydrants, two 2½-in. nozzles, or outlets, are commonly provided.

In municipalities where the fire department is equipped with steam fire engines or motor-driven pumping engines, the usual practice is to install hydrants having in addition to the 2½-in. hose outlets, a 4½-in. outlet to which the suction hose of the pump can be attached.

Desirable practice in this regard is indicated by the requirements of the National Board of Fire Underwriters. In the "Standard Schedule for Grading Cities and Towns of the United States with Reference to their Fire Defences and Physical Conditions," published by the National Board of Fire Underwriters, is found the following:

> "Hydrants shall not have less than two 2½-in. outlets and also a large suction connection where engine service is necessary."

Where the pressures in the distribution system are sufficient to permit satisfactory streams direct from hydrants, pumping engines may not be required by the Underwriters' schedule, but the proportion of municipalities where pumping engines are not used is decreasing. The modern motor-driven pumping engine with its greater speed of travel is being more generally adopted by fire departments than was the case with the steam fire engine. Furthermore, there appears to be a tendency to decrease pressures in distribution systems to the point of furnishing satisfactory service for domestic needs, and to throw the burden of developing fire stream pressures on the fire department apparatus.

Therefore, it may be expected in the future that there will be a more general use of pumping engines by fire departments, and, accordingly, hydrants, connections, and distribution systems should be designed with this fact in mind.

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Service Required of Hydrants and Effect of Pumping Engines.

An example of the severe tests to which hydrants in the larger cities may be put, is illustrated by incidents at a four-alarm fire on Congress Street, Boston, July 18, 1923. The writer is indebted to George H. Finneran, Superintendent Water Service, Boston, and E. M. Byington, Superintendent of Construction, Boston Fire Department, for the following details:

One hydrant of the Boston post type, having one $2\frac{1}{2}$-in. hose outlet and two $4\frac{1}{2}$-in. steamer outlets, during the early stages of the fire, had a connection by means of a large suction hose from one $4\frac{1}{2}$-in. outlet to a steam-driven reciprocating engine of about 750 gal. per min. capacity. The $2\frac{1}{2}$-in. outlet was connected by means of a large suction hose and reducer to a motor-driven rotary pump of about 1 000 gal. per min. capacity. With these two engines in operation, there was a noticeable vibration in the hydrant barrel. This hydrant is set in a chamber, and the hydrant barrel is not supported at the street level, the only rigid support being at the base and at the connection with the main. Additional streams were required and the so-called " Horseless Engine " was connected to the other $4\frac{1}{2}$-in. outlet. This engine is steam propelled, and has a stream-driven reciprocating pump of about 1 100 gal. per min. capacity. There is no record of the actual rate of flow of water through the hydrant, but the rate of draft was probably at least 3 000 gal. per min. with the three engines as operated. Under these conditions, the hydrant barrel swayed violently, and although various means were tried to provide support, it finally became necessary to disconnect the " Horseless Engine " to prevent wrecking the hydrant. A large air chamber was then brought to the scene and inserted between the pump suction and the suction hose leading to the hydrant outlet. This chamber had a dome top, was 10 in. in inside diameter, about 28 in. high, and was restricted to $4\frac{1}{2}$ in. in inside diameter at the base, where the connections were made. The installation of this air chamber reduced the vibration in the hydrant considerably. It was found by trial that the chamber was most efficient when attached to the pump suction rather than to the hydrant outlet. The water mains supplying this hydrant were ample in capacity, as shown by the fact that the pressure did not drop appreciably during the fire (see Fig. 1), but the hydrant lateral was only 6 in. in diameter and the flow in the hydrant pot was restricted by the valve, which opened in the direction of the flow of water. This was the second instance of trouble with this hydrant under similar conditions. In fact, whenever the " Horseless Engine " has been used with other engines at a large fire severe vibration has been caused at the hydrant.

The Congress Street fire, which was located in a five-story warehouse in a high-value, wholesale district, outside the limits of the high-pressure water system, furnishes an interesting subject for study of the demands on the water-distribution system during a large fire. Chief John O. Taber

kindly furnished details of the fighting of the fire. A description of the fire will be found in " Fire and Water Engineering," August 1, 1923, p. 217.

There were 16 engines in use, connected to 9 post hydrants and 2 Lowry flush hydrants, and furnishing a maximum of over 12 000 gal. per min. of water to 18 900 linear feet of hose. The average pump pressure was 143 lb. per sq. in., and varied from 120 to 200 lb. per sq. in. The apparatus and equipment was handled by 240 firemen.

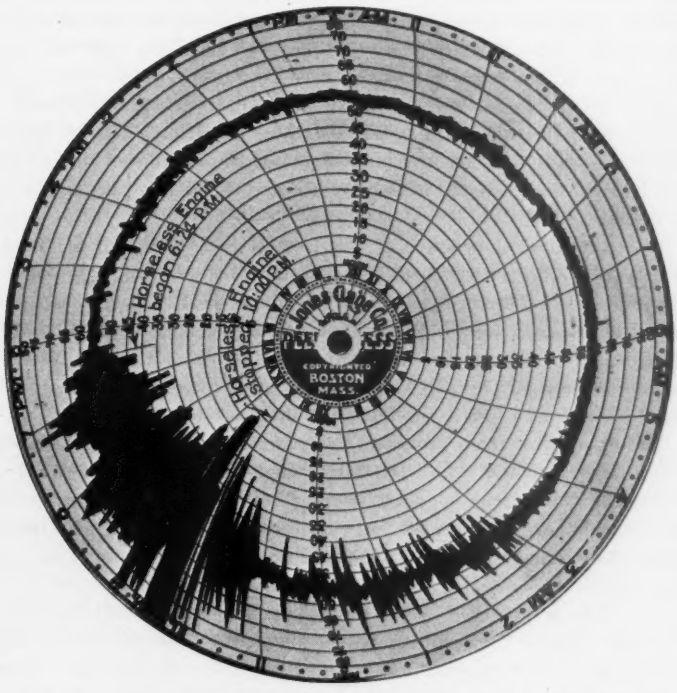

FIG. 1. — FLUCTUATIONS IN WATER PRESSURE IN DISTRIBUTION MAINS CAUSED BY WATER HAMMER FROM PUMPING ENGINES CONGRESS ST., BOSTON, MASS., FIRE, JULY 18, 1923.

A short distance from the scene of the fire in one of the fire department engine houses was a recording pressure gage, which made an interesting record of the water hammer in the distribution mains referred to above. This is shown in Fig. 1. The first alarm was sounded at 6.07½ P.M. The first engine began to pump at 6.10 P.M., and the " Horseless Engine " began to pump about 6.24 P.M., and was shut down about 10.00 P.M. Its effect was very marked. After the air chamber was installed it was again used on watch lines for about 39 hr.

At a fire in Charlestown where the " Horseless Engine " was used

the vibration was sufficient to loosen the four bolts which hold the base of the hydrant, and the hydrant barrel came off while the engine was working.

At a fire in Brighton two steamers of the reciprocating-pump type were attached to the two 4½-in. outlets of a Boston post hydrant. One of the steamers was supplying one line of hose. The other steamer for some reason was not working. A motor-driven pumping engine was then attached to the 2½-in. outlet, and four lines of hose were attached to the pump, each line supplying 1¼-in. nozzles. The pump was operated showing 12 in. of vacuum on the suction, but it was impossible to get satisfactory service, and it was found necessary to remove one of the hose lines to one of the steam-driven engines, leaving three lines on the motor-driven pump attached to the 2½-in. outlet. From this observation and others, Mr. Byington is of the opinion that three streams of perhaps 250 gal. per min. each, or a total of 750 gal. per min., is about the maximum rate at which water can be satisfactorily drawn by a pumping engine through a 2½-in. hydrant outlet.

It is the general practice of the Boston Fire Department, when an engine responds to a first alarm, to use a 3-in. soft-suction hose which has 4½-in. couplings, and although the intention is to attach the engine to a 4½-in. outlet it sometimes happens that a 2½-in. outlet is used, if conditions seem to make it the most convenient outlet to use. Engines responding to second alarms use the 4-in. hard-suction hose, which has 4½-in. couplings and attach the hose to a 4½-in. outlet, if there is one available.

Serious trouble from vibration in hydrants in Boston has been almost entirely limited to the use of the "Horseless Engine," but at times when three of the smaller engines have been attached to one hydrant, considerable vibration has been noticed in the hydrant. If these hydrants had been buried in earth rather than installed in a pit, there would not have been as much trouble.

Instances have come to the writer's attention where hydrant barrels have been split or the hydrant blown off at the base due to the rapidly recurring water hammer or vibration resulting from the operation of pumping apparatus at high rates when connected to hydrants inadequately served by the distribution system. With reciprocating or rotary pumps which are of the positive displacement type of apparatus, and under such conditions it is possible to create a suction greater than can be satisfied by the flow of water. This apparently causes the water to come intermittently accompanied by violent water hammer, and stresses are set up, which the cheaper types of hydrants or poorly constructed connections and pipe lines cannot withstand.

Obviously, the operator of the pumping engine should neither be required nor allowed to speed up the pump beyond the capacity of the pipes and hydrant to deliver the water.

Difficulties of this kind are not likely to occur with centrifugal pumps.

The smaller sizes of motor-driven pumping engines are not equipped

with vacuum chambers, but the larger sizes such as 1 000 gal. per min. capacity and over, have small vacuum chambers. Where vacuum chambers are provided, but little vibration is caused by the operation of the rotary pumps and even where no vacuum chambers are provided the vibration from the rotary pumps, which operate at relatively high speed, is much less than that obtained from the operation of the old type of reciprocating steam-driven pumps. It has been found that after from one to two hours' continuous operation vacuum chambers lose their air content and it becomes necessary to stop the engine and drain out the water. Therefore, some vibration may be transmitted to the hydrant even with motor-driven rotary pumps equipped with vacuum chambers.

While it is true that when running at equal rates of discharge, the steam-driven reciprocating pump will cause a greater vibration than the motor-driven rotary pump, there seems to be some ground for thinking that the danger of getting vibration is a little greater with motor-driven pumps due to the greater ease with which they can be driven at full capacity or even under an overload.

Fortunately, experiences like the foregoing are not of frequent occurrence. Normally, a hydrant is called upon to supply water for two or three lines of hose at a maximum rate of perhaps 600 to 750 gal. per min. or less.

At these rates of discharge and where ample pressure is availabel, the size of outlet used and method of connection are not matters of great importance.

In districts where the ordinary pressure maintained in the distribution system is 75 lb. per sq. in. or over (omitting special high-pressure systems), it has frequently been the practice to install hydrants with hose outlets only, and to omit the steamer outlet. This seems to the writer ill-advised for two reasons:

First, in case of a serious conflagration a larger number of fire streams than usual will be used, and the pressure in the entire district will be materially reduced — probably to the point of requiring engine service to maintain satisfactory fire streams. For the ordinary fire of course, this is not so.

Second, it occasionally becomes necessary, due to unusual conditions, to connect hose lines to a hydrant located some distance from a fire, with the result of lines 1 500 to 2 000 ft. or more in length. Under such conditions even 90 lb. per sq. in. pressure will not give satisfactory service, and the services of a pumping engine will be desirable to raise the pressure, perhaps, up to 250 lb. per sq. in. Communities that at present have no engines of their own occasionally require help from outside, and furthermore, it will not be many years before pumping engines will be used by practically all fire departments.

Therefore it would appear that the slight additional cost necessary to provide at least one steamer outlet, is justified.

Loss of Head in Hydrant Outlets.

The National Board of Fire Underwriters in the "Standard Schedule," page 32, specify.

> "Hydrants shall be able to deliver 600 gal. per min., with a loss of not more than 2½ lb. in the hydrant and a total loss of not more than 5 lb. between the street main and outlet . . . ."

Newcomb's Holyoke hydrant tests reported in the JOURNAL of the New England Water Works Association, December, 1907, page 421, show for the hydrants without independent gate valves on the outlets and with barrels 5 in. in inside diameter and greater, losses due to friction varying from 1.21 to 3.21 lb. per sq. in. at a rate of flow of 500 gal. per min. with one fire stream. For the hydrants having independent gate valves on the outlets, the losses due to friction varied from 2.92 to 8.28 lb. per sq. in.

The loss of head due to friction of flow of 600 gal. per min. through a 2½-in. outlet averages about 2 or 2½ lb. per sq. in., if there is no independent gate valve on the outlet, and for a 4½-in. outlet only about one-tenth as much, according to George W. Booth, Chief Engineer, The National Board of Fire Underwriters.

600 gal. per min. flowing.
2½-in. diameter outlet, velocity 39.4 ft. per second, velocity head 24.14 ft.
6-in. diameter barrel, velocity 6.8 ft. per second, velocity head 0.72 ft.
Difference in velocity head = 24.14 − 0.72 = 23.42 ft.
2½ lb. per sq. in. is equivalent to 5.8 ft. head of water.
5.8 ft. due to friction + 23.4 ft. due to velocity = 29.2 ft.

To the friction loss of 2½ lb. per sq. in. must be added the head necessary to develop the required additional velocity of the water in the outlet over that in a 6-in. hydrant barrel amounting to 23.4 ft., thus making a total head of 29.2 ft. necessary in the main at the elevation of the center of the hydrant outlet. While some of this head may be recovered after passing the outlet, particularly if an increaser is used between the outlet and the suction hose, the most of it is probably lost. For higher rates of flow, the loss of head will be greater. These losses appear sufficient to justify wherever practicable the use of the steamer outlet for engine suction rather than to make the connection by a Siamese coupling to two 2½-in. outlets. It may be that where ample pressure is available, the loss of head suffered by using a larger suction hose with a reducer connected to one 2½-in. outlet is not sufficient to offset the advantage of handling the smaller coupling. If, however, there is an independent gate valve on the outlet, the loss of head is likely to be objectionably large.

General Practice in Regard to Hydrant Outlets.

The following comments by George W. Booth are the results of the observations of the engineers of the National Board of Fire Underwriters:

"Our engineers are in frequent touch with fire chiefs and water-works superintendents and have an excellent opportunity to find out their opinions and to learn of local conditions.

"We have never heard of a case where damage to the hydrant or to the main resulted from the use of the large outlet. There is a possibility of the hydrant nipple being jarred loose as a result of vibration transmitted from the steamer or the motor pumper especially if a stiff suction is used; however, this possibility is just as likely to occur with the 2½-in. outlet as with the larger one.

"Our engineers report that practically all fire chiefs in the East use the large outlets when provided and would very much object to the installation of hydrants not having large outlets. In the Middle West the testimony is that large outlets are generally used when available. There are, however, many municipalities which have water works designed to carry a high enough pressure during fires to supply streams direct from hydrants, which have therefore only the 2½-in. outlets. Now that the use of pumpers is becoming more common, there is a tendency to reduce pressures and this in our opinion has some advantages.

"In many of the larger cities, Detroit and St. Louis, all or nearly all hydrants have *none* but large outlets.

"While it is true that the function of the fire engine is to furnish water at the necessary pressure, it is also true that the capacity of the pumper is primarily determined by the horse power of the engine and every pound of pressure that can be applied to the suction side of the pumps increases the capacity of the pump, and friction losses which can be readily eliminated should be avoided. Even though the pressure at the hydrant may be normally sufficient to furnish adequate supply through a 2½-in. outlet, the local friction losses in the mains which result from the use during a large fire of excessive quantities of water within a small area, will so reduce the pressure that a larger outlet is required for adequate supply.

"To sum up, I believe there is no valid argument against the use of the 4½-in. outlet and a number of good arguments in its favor."

In response to the writer's request, E. V. French, President of the Arkwright Mutual Fire Insurance Company, ascertained the views of their engineers and wrote the following comments:

"We have been unable to find any experience which would indicate that a 4½-in. hydrant outlet constitutes a hazard to either hydrants or distribution systems. A 4½-in. hard-suction pipe would probably transmit somewhat more vibration from an engine than a 3½-in. or 2½-in. hard pipe, but we should not expect the difference to be serious or of any real importance with a properly designed hydrant.

"In cities with good water pressures, such as Woonsocket, R. I., engines take water sometimes through ordinary 2½-in. hose using two hydrant outlets. In New Bedford experience has shown that sufficient water could not be obtained with two 2½-in. connections if the water pressure in the mains fell much below 50 lb., so that in all cases in New Bedford the 4½-in. suction connection is used. There have been cases where a single 2½-in. soft-hose connection has collapsed under the suction produced by the engine.

"In some cities 4½-in. hard hose is used with a reducing coupling which can be attached to the 2½-in. hydrant outlets, thus restricting the inlet for only this single point and consequently obtaining a good deal more water than if the suction pipe was 2½-in. all the way. However, in the majority of cases in this vicinity (Boston), at least, 4½-in. hard-suction pipes are used."

John S. Caldwell, Engineer, New England Insurance Exchange, expressed his views on this subject as follows:

"We have never found in our work here in New England any sentiment among either water-works or fire department officials which would tend to discourage the installation of the large connection.

"Relative to the vibration which may be experienced in the hydrant due to the connecting to a modern motor pumping engine through the 4½-in. connection, would state that I do not believe this is so, as we would expect more vibration from the old reciprocal type of pump when in use with a steamer than what we would get with the more modern machine. Of course, it is common practice for fire departments to use a 4½-in. by 2½-in. reducer for connection to engines where only a small quantity of water, like a single stream, is desired, but when the engine is required to work up to capacity, unless they happen to be on a hydrant with exceptionally good pressure, they very frequently are unable to get ample capacity through a 2½-in. connection.

"I think I am perfectly safe in assuring you that there is no sentiment here in New England, as we have observed the conditions that would tend to discourage the installation of the larger engine connection and, as stated above, I believe the opposite is true, namely, that there is a movement on foot in the replacement of existing hydrants with ones having the larger connection, and in our grading of the fire protection throughout the different cities and towns we make a deficiency charge for the lack of engine connections on hydrants."

Chief Ross B. Davis, Bureau of Fire, Philadelphia, by courtesy of S. M. Van Loan, Deputy Chief, Bureau of Water, contributed the following:

"Our hydrants which have a 4-in. outlet and 4½-in. suction hose permit us to take three and four lines from the one steamer, and we would never allow over two lines to be taken from a pumper or steamer with a 2½-in. suction, unless reducing the tips of the nozzles, and that reduces the volume."

C. M. Saville, Manager and Chief Engineer, Board of Water Commissioners, Hartford, Conn., stated that all of the hydrants being installed in Hartford, Conn., have two 2½-in. hose outlets and one 4½-in. steamer outlet.

William W. Brush, Deputy Chief Engineer, Department of Water Supply, Gas and Electricity, New York, wrote:

"Our standard hydrant has one 2½-in. and one 4½-in. outlet. We have never had any complaint that has come to my knowledge of difficulty through the use of the 4½-in. steamer outlet. I personally believe that it is a mistake to use small outlets, that there is no danger to the hydrant with the 4½-in. outlet, and that with the increase in the size of the pumping engines the standard hydrant should carry a 2½-in. and a 4½-in. outlet."

George A. Carpenter, City Engineer, Pawtucket, R. I., reports that there are *no* hydrants in the city with 4½-in. steamer outlets. This appears to be contrary to the practice of most New England cities. Inquiries by the writer in Indianapolis, St. Louis, and Dayton, where large steamer outlets are generally provided, failed to disclose any instances of trouble which could be attributed to the use of such outlets.

Support for Hydrants.

The hydrant outlets must be securely fastened to the hydrant barrel, which fact is recognized by the manufacturers of high-grade hydrants. Not all water-works builders, however, recognize the necessity of securely fastening the hydrant barrel to the lateral and main to prevent its being blown off. Where the main pipe is but a short distance from the hydrant, chains or bolts may be used to secure the hydrant. Concrete blocks cast behind the hydrant have also been used. Where dependence is placed on earth back fill or loose rock fill, the hazard to the hydrant is much greater. It is true that many hydrants have been set without special precautions being taken to properly support them, but it cannot be considered good practice. Earth back fill, well rammed, will provide sufficient lateral support except at the back. Where the hydrant is set in a heavy pavement, or concrete sidewalk, ample lateral support is ensured, but such support should not be relied upon to secure the base of the hydrant. If the hydrant is adequately supported and of first-class design and manufacture, it may safely be depended upon in time of emergency.

Conclusions.

1. The use of 4½-in. steamer outlets on hydrants, in addition to two 2½-in. hose outlets, is desirable where pumping engines are likely to be used. In the larger cities it is probably better to provide two large steamer outlets and only one 2½-in. outlet.

2. During the past ten years there has been a tendency to increase pressures in distribution systems, but now the trend of good practice appears to be toward a reduction to the former pressures to provide for domestic service, with dependence on fire department pumping apparatus for fire stream pressures.

3. Steamer outlets should be provided even where the ordinary pressure is ample for two-hose streams, to make possible the draft of water at higher rates with a pumping engine in case of a serious fire or other emergency.

4. The distribution system should be capable of delivering water to the hydrants at rates consistent with the demands of modern fire-fighting methods.

5. During a serious fire, hydrants may be subjected to considerable vibration due to heavy drafts of water. To prevent failure in such a critical time, the hydrants should be of heavy construction and firmly supported. Special precautions should be taken to prevent the hydrant blowing off from the lateral at the base.

6. According to the Underwriters' rating a municipality will be penalized if there is a deficiency in steamer outlets, where engine service is required.

7. It is desirable to install steamer outlets even where a pressure of 75 lb. per sq. in. is ordinarily maintained, to provide for engine service in emergency.

8. There appear to be several good reasons why at least one large steamer outlet should be provided on every hydrant in a standard pressure water distribution system, and no valid reason against providing such an outlet.

Discussion.

Mr. S. H. MacKenzie.* I would like to inquire what type of hydrants the speaker would recommend for the places which have long lines of 4-in. and 6-in. main pipe. Would the centrifugal pump for fire service be the most satisfactory to use, and would there be less danger with such a pump of drawing more than the safe capacity of the main?

Mr. Marston. In regard to the centrifugal pump for fire department use, I am not an authority, but I understand that fire department officials do not generally favor centrifugal pumps because they do not get the same amount of suction with them that they can with the rotary pumps.

On the type of hydrant, that is pretty hard to say, not knowing the conditions, but my impression is that with 4-in. and 6-in. mains feeding the hydrants and with the motor-driven pumping apparatus, there would be times when the demand would be greater than the mains could supply. Even then you would be better off with a $4\frac{1}{2}$-in. outlet than with a $2\frac{1}{2}$-in. outlet, which would further throttle the pump suction.

Mr. MacKenzie. I was not thinking so much of the size of the outlet of the hydrant as of the type of pump. Would the danger from water hammer and overdraft be less with a centrifugal pump than with the other types used?

Mr. Marston. You mean, the centrifugal pump by the fire department?

Mr. MacKenzie. Yes. For instance, a short time ago, when flushing, we opened a hydrant at a low point and drew the water from the high points on the line. The question arises in my mind what will happen when a fire pump is attached under such conditions and what style of pump is most suitable for use?

Mr. Marston. I doubt if you would get any damage with a centrifugal pump, but you might with a rotary pump. The damage might occur in the hydrant, or near-by mains, or in the services, wherever there was a spot too weak to resist water hammer. If the water distribution system is well built and the pumping engine reasonably well operated there would be but little danger of such damage.

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* Superintendent, Water Department, Southington, Conn.

MR. HENRY T. GIDLEY.* I would like to ask what reason they give in New York City for having only one $2\frac{1}{2}$-in. outlet with the $4\frac{1}{2}$-in.?

MR. MARSTON. I do not know the reason.

MR. J. M. DIVEN.† The high pressure have two $2\frac{1}{2}$-in. and one $4\frac{1}{2}$-in. outlet.

MR. W. C. HAWLEY.‡ I have been particularly interested in this paper because I have had this problem put up to me, although in a different way. I agree with Mr. Marston that for ordinary pressures the $4\frac{1}{2}$-in. nozzle is desirable.

The problem which I have had was a demand for $4\frac{1}{2}$-in. nozzles with pressures from 140 to 175 lb. I made inquiries of a number of men who had had experience, and almost without exception they said that under those circumstances they would not set a hydrant with the large connection, it is not necessary. I only found one place where they were doing it, but in that case when the firemen connect with those hydrants, carrying, I believe, something like 200 lb. pressure, they put on a reducer to $2\frac{1}{2}$ in. and use no steamer or pump.

We had an experience with a test, so-called, which was made during January of this year. The test was made by the municipal authorities without any notice to the water company. Seven fire streams were thrown through various lengths of hose ranging in length from 350 to 500 ft. and through $1\frac{1}{8}$ to $1\frac{1}{4}$-in. nozzles. Then they attached a pump to a hydrant diagonally across from one of the hydrants already in service, to which hydrant there were 500 ft. of hose with a $1\frac{1}{8}$-in. nozzle. No pressures were taken at the hydrants either before, during, or after the test. The only pressures that were taken were at the nozzles while the seven fire streams were being thrown, and after the pump was started they again took the pressures at the nozzles. The gentleman who was supposed to be running the test broke into print the next day with the statement that " millions of dollars' worth of property and hundreds of lives were jeopardized " because they only had from 40 to 75 lb. of pressure at the nozzles. Reference to the tables will show these to be " good " to " unusually strong" fire streams.

There was one interesting thing about that test. It happened that one of our men had been in the office late that evening and on his way home saw what was going on. When the pump was in service it was throwing a little less than 800 gal. per minute, and the other streams in the neighborhood 2 100 or 2 200 gal. per minute more, as I remember it. Under those conditions there was 40 lb. pressure on the suction side of the pump. The order was given to shut down the pump, and later it was started up again. When they shut it down they closed the hydrant. When the pump was started the second time they " opened " the hydrant, but there

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* Superintendent, Fairhaven Water Company, Fairhaven, Mass.

† Secretary, American Water Works Associaton.

‡ Chief Engineer, Pennsylvania Water Company, Wilkinsburg, Penn.

was no pressure on the suction side until our man found that the hydrant was only partly open. He opened the hydrant and then there was 100 lb. pressure on the suction side. This hydrant did not have a steamer nozzle. The water was taken from a 2½-in. hose connection.

The failure to open a hydrant is one of the things that has given me more trouble, so far as my relations with the fire department are concerned, than any other one thing. I remember a very serious fire where we were blackguarded by the firemen for lack of pressure. It happened that one of the commissioners came along and opened the hydrant, and then they had an abundance of water. The firemen had opened it only three or four turns. We have been up against that a number of times, and I think that is one of the things which we should watch, especially in the case of volunteer fire departments, although I have known such things to happen in paid departments.

Referring again to the test which I have mentioned: about four months later we had a real test at a fire in the same block. The fire got a bad start in the basement of a large building in a thickly built-up district. Seven fire streams were in service, most of them from the same hydrants which had been used in the test. There was an ample pressure and an abundance of water and the fire was soon extinguished.

We have decided not to set hydrants with large connections. We have an abundant pressure, and, frankly, I am afraid of the jar of the pump shaking the hydrant from the lateral. We have had trouble with steam fire engines, although no hydrants have blown off, but I know of cases where that has happened, and I am afraid with our pressures, of what may happen.

The municipality which wanted us to set hydrants with 4½-in. nozzles was very insistent, and we finally replied that we would set the hydrants if the municipality would assume the responsibility for any accident which might happen. They would not assume that responsibility, and we set the hydrants with the small nozzle.

Mr. Caleb M. Saville.* I was interested in what Mr. Marston has said about losses of pressure in the hydrants. We have made quite a number of tests of hydrants at Hartford, to ascertain the loss of pressure in various parts of them, and the information thus far indicates that the principal losses are in the outlets. Most of the hydrants that are made, even with 4-in. barrels, seem to have plenty of waterway, and if the hydrant manufacturer could be induced to make some improvement in the 2½-in. outlets it would be of a considerable benefit.

Mr. Marston spoke of a tendency to reduce pressures. I am not sure that that is a general condition, although it may be so in towns or cities where a pumping plant is used; that is, where it is not necessary, perhaps, to have the higher pressures all of the time. In those cities that are fortunate enough to be supplied by gravity it seems to me that there is a tendency

* Chief Engineer, Board of Water Commissioners, Hartford, Conn.

the other way; that is, to get higher pressures and put on reducing valves in the lower parts of the district if the pressure is too high. In Hartford we recently have had several very high buildings erected and the pressure is none too high. In the lower part of the city, the pressure is high — 100 to 125 lb. — and reducing valves are being put on to some extent. In the higher buildings and in the higher parts of the district the pressure now used has eliminated the use of independent pumping engines, greatly to the pleasure of the people there supplied.

MR. DAVID A. HEFFERNAN.* We have a Mutual Aid agreement with a contiguous municipality. At a two-alarm fire one cold day last winter we experienced a rather unusual occurrence.

Our hydrant nozzles are equipped with standard thread. The municipality mentioned has a mongrel thread on its 4-in. suction. Therefore, both fire departments carry adapters. When more apparatus responded which did not carry the adapter the 4-in. suction could not be used and much valuable time was lost before these outside firemen discovered that the thread was different from the one they were used to.

The same fire department experienced trouble with every Milton hydrant they tried to operate. Their hydrants are of the compression type, while ours are of the sliding-gate type. The latter open harder. In two cases these outside firemen were unable to open the hydrants with their short wrenches and thought they were frozen. In each instance the hydrant was opened by water-department employees.

I have always considered it essential for a water-department man to attend fire alarms. In the case of our department this is simplified as two of our men are members of the call force.

MR. MACKENZIE. We had a little experience a few days ago which showed the great value of pumping apparatus, and also the value of uniform threads. We had a fire at a camp ground in our town, and the fire department from Plainville, three miles away, and New Britain, eight miles away, responded. Plainville furnished the hose and New Britain the pump. As the fire was 2 600 ft. from the hydrant the stream was almost useless until the pump was connected. Coöperation, uniform hose threads, and a pump saved all but two or three cottages at the camp grounds.

In many communities the mains are small and the hydrants are located far apart and many also have high sections with low pressures. Under such conditions a combination auto chemical and pump is a valuable asset, as shown in the case above.

MR. CHARLES W. SHERMAN.† What I have to offer is not on the subject of Mr. Marston's paper, but it is suggested by one of the points raised by Mr. Heffernan and may not be out of place in this discussion; that is, the lack of knowledge on the part of some fire departments, par-

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* Superintendent, Water Works, Milton, Mass.
† Of Metcalf & Eddy, Boston, Mass.

ticularly the smaller ones, of the proper operation of hydrants or any other water-works apparatus.

It came to my knowledge two or three years ago that in a small town the fire department complained to the water department that the hydrants were in bad condition. They said they had very nearly lost a valuable building because they could not operate one hydrant. This resulted in a joint inspection by the water and fire departments of all hydrants in the town, and in the course of that inspection it developed that the hydrants themselves were all in good mechanical condition, except the operating nuts of some, which had been badly chewed up. In a few cases it appeared that that had resulted from the more or less common use of a Stillson wrench when using hydrants for other than fire or water department purposes; but in a number of cases it developed that it had come from the use of the fire department wrenches, and further investigation proved that instead of using regular hydrant wrenches they had some wrenches made by a blacksmith which were not properly fitted to the hydrant nut.

Mr. R. W. Wigmore.* I am particularly interested in the paper because of the fact that practically all the suggestions given by the paper have been followed in the city in which I live.

Speaking particularly of the lack of coöperation between the water department and the fire department, I would say that we have a man who has absolute charge of the hydrants. He attends every fire; in fact, he is at the fire almost as quickly as the fire department, so that if anything is wrong with the hydrant he can have it attended to at once. He is a practical man. In the winter time, in very severe weather, we have a daily inspection of the hydrants, and in a winter that is not so cold, we have an inspection every other day. So that it is almost impossible for a hydrant to be wrong under these conditions.

I would like to ask Mr. Marston what size lateral he would suggest from the main to the hydrant. In our case we use nothing smaller than a 6-in., even with an 8-in. main. Of course where the main is smaller we use a 6-in. entirely.

Mr. Marston. Where the hydrant connection is of short length, 6-in. pipe is commonly used, and is satisfactory. Smaller pipe should not be used. For important hydrants of large size (with 8-in. barrels) connected to water mains of ample capacity, an 8-in. connection is justified.

Mr. Henry V. Macksey.† Referring to just one point outside of the paper, which was brought up by our President-elect, regarding the coöperation between the fire department and the water department. I believe in coöperation, but I do not believe that real coöperation consists of putting one man's duty and responsibility upon another man. Now, instead of being so insistent on having a competent hydrant man from the water department attend every fire and be able and willing to tell every

* Commissioner of Water and Sewage, St. John, N. B.
† Superintendent, Public Works, Framingham, Mass.

fireman how to operate a hydrant, I think, if there is to be coöperation it should be in the water department insisting that the firemen should be sent to them to be instructed how to operate hydrants properly, and that it is not so necessary that there should be a competent man from the water department to open the hydrants as it is that there shall be competent men from the fire department to open the hydrants. In other words, when the fire department asks you to coöperate you should do so, but do not assume the responsibility of operation. Where the authority is, there also should the responsibility be, and when the fire department takes charge of a hydrant at a fire, a water department man has no right to interfere, and has no authority there until he is called in by the fire department, and it should not call him until the hydrant fails to work properly.

Therefore, I believe that it is good practice to have a competent water department man at the fire in case an accident occurs, or the firemen, either due to excitement or ignorance, make a mistake in the operation of the hydrant. Then the water department man should be there, if possible, to help. But that is not the principal duty of the water department in connection with hydrant service. The principal duty of the water department is to make the coöperation mutual and to instruct the firemen as needed and to advise them to send their wrenches to the water department, to see that they are properly made. We all know in time of excitement a fireman will use a Stillson wrench, and if nothing else is handy you cannot blame him even though he injures the hydrant stem. The water department inspector after the fire should take care of that trouble even if it requires a new stem.

Your coöperation is needed to instruct firemen how to operate a hydrant in time of fire, but not during the fire.

MR. HEFFERNAN. I would like to state that the water department men are members of the fire department also. I am a member myself. So that is the reason why we do not like to have anything put over on us if we know it is not the fact. It is like the case of the frozen hydrant.

MR. DIVEN. There is an adjustable fire hydrant which can be adjusted if the nut is partly worn, which fire departments might use. Mr. Saville spoke of the lessening resistance in the outlets of hydrants. I asked him how he proposed to do it. I would suggest to him that there is a committee on Standard Fire Hydrants still in existence in the Association, and he might take the matter up with them.

A MEMBER. I just want to suggest that the presence of the Stillson wrench might be laid to the average water-works superintendent, for the reason that he does not have his hydrant connection, $4\frac{1}{2}$-in. in diameter, loosened sufficiently for the average fireman to open it, and the fireman always provides himself with a Stillson wrench so that he can open it in an emergency.

MR. HEFFERNAN. As a matter of coöperation I had three wrenches made, and I presented them to the department, so that they would not have any further trouble. Of course the cast-iron wrenches are 2 ft. in

length and no leverage on them. The hydrants are of the compression type and the gate hydrant works harder.

PRESIDENT SANDERS. I would like to get a little information myself. Of course the President should not enter into the discussions; but we have a large number of individual valve hydrants, and at every fire we have to use one of the individual valve hydrants, and when they get through using it and we get back to the hydrant, we almost always find the valve in the bottom of the hydrant. It does not seem to make much difference what kind of hydrant it is. I would like to know if it is the general custom of the men present here to use individual valve hydrants, or if they put the valve on the nipple on the outside of the hydrant? Of course that is done in a factory yard, but whether that is a proper thing on a street is another matter.

MR. MARSTON. I believe the best practice is to omit individual gate valves from hydrant outlets, particularly $2\frac{1}{2}$-in. outlets. The fire department can easily carry such valves. The valves will then be removed after the hydrant has been used, and the trouble referred to will be obviated.

MR. SAVILLE. I would say that in Hartford they have one or two of those individually gated hydrants, but in other cases the fire department carries independent valves with them which they put on themselves.

MR. SYDNEY L. RUGGLES.* It is the practice in our city to have one or two men in the water department as call men in the fire department, so that in the case of a general alarm they go out and act as members of the fire department. Also, of course, when the firemen have drills, the call men, the water department men, are expected to go, and they are assigned to handling the hydrants in the assignment of the call men.

MR. GIDLEY. Some of the remarks of the former speakers make me think of some of my experiences. Just this summer they bought a new pump in the town. Before they bought the pump there was great discussion of whether we could furnish enough water for the pump. So when they got the pump they took it out, of course without notifiying the water department, and put it on a dead end, and were very much astonished — we had 85 lb. pressure. They worked the engine full capacity and they still had all the water they wanted, and they were very much surprised at that. So they took it out again without telling us, and that time they put on all the streams they could in that vicinity, and they were satisfied we had enough water to run the pump. But a short time after that there was a still alarm and they attached the pump to the hydrant, and they said they did not get any water from it. They telephoned to the pumping station to know if we had any water in the mains. The trouble was that they had only opened the hydrant a few turns, and when they opened the hydrant in good shape they got plenty of water. That seems to be a great trouble with them. Of course in a general alarm a member of the water department would probably be there, but in that case of course he didn't know anything about it.

* Superintendent, Water Department, Barre, Vermont.

THE CARE OF LARGE WATERSHEDS.

BY FREDERIC I. WINSLOW.*

[*Read September 19, 1923.*]

After the various excellent papers which have preceded this one, and with those which are to follow in mind, I confess to some slight feeling of embarrassment in presenting a paper on a subject which can hardly claim the merit of possessing much that is new to those of our members having the care of watersheds. But as there are many persons occupied in work similar to what is described here, it is hoped that the paper may at least be of some value to water-works men.

In the annual report of the Metropolitan Water Board for the year 1917, a sentence occurs expressing the opinion of the Board as follows: "It may be claimed with entire justice that the ability adequately to maintain a complicated system of water supply requires qualifications not inferior to those of the men employed in the original construction of the works, however they may differ in character." While the writer cannot wholly agree with the above high estimate of the ability required to maintain existing works, realizing that designers, construction engineers and foremen usually receive a greater remuneration than those on permanent work, and usually that after the larger jobs are completed the better or higher grade of men go and the inferior ones remain to carry on the work; yet the fact remains that there is a considerable degree of responsibility in the successful operation of large water-works systems.

Perhaps the first care on a watershed to-day is to control a large area on the perimeter of the main supply reservoirs. Even the private companies feel impelled to do this as we have seen at Bridgeport and elsewhere. With a sufficiently wide right of way around the reservoirs, with adequate laws to prevent boating, bathing, and other forms of pollution, and a sufficiently large patrol force to keep the public in some awe of consequences, the water drinker may feel fairly safe, or as safe as one could feel with an unfiltered and untreated water.

The matter of planting all available areas has been so thoroughly discussed before you that I would not take the time to enter upon it further than to emphasize the importance of planting and to say that in general probably some variety of pine is the best adapted to New England. I quote on this point, E. H. Frothingham (Bulletin 13, Dept. of Argiculture, U. S.), who states; "Of all the trees of Eastern North America, white pine best combines the qualities of rapid growth, heavy yield and ease of management, but grows best in deep, fresh, loamy soils." He claims that

* Division Engineer, Metropolitan District Commission; Consulting Engineer, Framingham, Mass.

four to six per cent profit may be made on the investment, excluding taxation.

In a number of states wooded areas are exempted from taxation, either wholly or in part, when such areas are planted for the purpose of conserving a privately-owned water supply. The usual spacing recommended is six feet apart. Quoting again from E. H. Frothingham, "Balsam fir, which is planted to the extent of twenty per cent in New England, is inferior to white pine or spruce." As some question has arisen regarding the merits of white pine, I quote from a recent letter from C. R. Tillotson, Acting Chief, Branch of Forest Management, U. S. Dept. of Agriculture, who writes "As a precautionary measure, some foresters are advocating the substitution of red or Norway pine for white pine, at least in part." This statement is made relative to the damage to white pine from "blister rust," and Mr. Tillotson further states, "If allowed to go on unchecked, this disease will, in the opinion of the Forest Pathologists who have given it the most study, do a great deal of damage to white pine. These same men, however, are of the opinion that the disease can be kept under control through rather inexpensive measures, and that it need not therefore interfere with the growing of white pine in regions where the white pine is particularly well adapted for growth." It is customary to eliminate all raspberry and gooseberry bushes from the proximity of these trees. What is called paper birch is sometimes recommended, as this has considerable commercial value, being used for spools, shoe pegs, toothpicks, dowels, shanks, etc. Red spruce may also in some cases be planted to advantage, the wood being used in topmasts, framing, and in vessels where oak is scarce.

It is certainly important to plant trees wherever possible, as according to the best authorities the supply of lumber in this country will be exhausted in fifty years. Massachusetts now imports about eighty per cent of her lumber supply, where within the memory of men still living she was a large lumber exporting state. It is refreshing to note that a few towns are even planting town forests, among these being three in Massachusetts, Fitchburg, said to be the first in the United States, Walpole and Brookline. The importance of spraying in the spring should not be forgotten. The customary strength of the arsenate of lead solution is 10 to 12 lb. to 100 gal., and 500 lb. of the solution will cover about one acre of grown trees.

This brings us to the matter of fire prevention, which is one reason for having a fairly large force of men, who spend a large portion of their time in trimming the trees, in cleaning up underbrush and in maintaining fire stops, which are ordinarily 40 to 50 ft. wide, and not over 600 ft. apart. All slash should be disposed of and material should not be piled in windrows as it is too easily spread, if a fire should start, as the use of water is rarely feasible.

The covering of large areas by watchmen is more of a coercive measure than anything else, as there is little doubt that where residents in camps

near a sheet of water can do so without the risk of being arrested they will use the water for almost any purpose. It is not always easy either to interest a judge in a violation of the law, especially where the water is taken from a small town for a larger one a long distance away, and local public sentiment has to be considered in the bringing of breakers of the law to justice. The inspection of watersheds for all sources of direct pollution, however, must be persistent and continuous, for here we have public sentiment on our side, as a rule.

On the Metropolitan system no cesspool or privy can be maintained within 50 ft. of high-water mark of any open waters pertaining to the system, nor can any noxious liquid be placed on the ground within 250 ft. of high water, and no stable nor henhouse can be maintained within 50 ft. of high water. Hospitals and slaughterhouses are compelled to conform to state laws in general relating to permission, etc. Cutting of ice is permitted under permit and inspection, and all droppings must be removed promptly. If all cutting could be made by the compact machines now on the market, it would be a step in advance. In the crossing of aqueducts, all pipes are or should be compelled to be laid with tight joints and no crossings should be made without previous notice, allowing opportunity for inspection and investigation.

Passing on to the subject of dams, the first and most important matter is that of observation of leakage. Usually, observation of the leakage through a dam is arranged for by providing a sump where a weir is sometimes built, permitting the observation of any change in the flow. Most dams leak to some extent, but those under the notice of the writer do not appear to show much change from year to year. If properly built, masonry dams do not require much attention except as to flow over or through them, and this is under regulation.

All permanent houses should be of a material other than wood, and especially the steps where exposed to the weather. A long flight of wooden steps exposed to the weather is especially to be avoided. It is found that buildings not occupied daily for carrying on work are liable to be vandalized to some extent, the locks being used as targets by those of a sporting turn of mind, so that it is well to paint them black or some color not likely to attract attention. The locks on the covers of aqueducts require some attention and should be operated frequently to insure their ease of operation when needed. No windows in this country can long remain without protection.

Culverts require attention, mainly to keep them open, and should be inspected periodically. No plants requiring fertilizers should be placed on the embankments, and they should not be used as pasture ground for cattle. All aqueducts should be patrolled frequently, twice, or oftener, a week. Fences must be built at points where trespassing is especially liable to occur. It is customary to take the heights of water in all reservoirs daily, and in certain cases three times, 7 A.M., noon, and 4 P.M., being

the most convenient. This is of course especially essential where the waste has to be figured from these observations.

Generally, the water level in the reservoirs is kept fairly low in the fall; all flashboards are removed, and preparations made for possible freshets. Provision should be made for as high a flow as would result from 1½ in. over the entire watershed — actual run-off in 24 hours. A little less than this was received on the Sudbury watershed in February, 1886. Flashboards are usually withdrawn by hand, but occasionally machinery is used for this purpose. In vertical dams, i. e., vertical on the lower side, air vibration is sometimes caused in the vicinity while heavy flows are passing over the dam, causing considerable rattling of windows, etc. A cure is generally effected by introducting some object such as a piece of timber or portion of a tree at one end of the dam so as to permit air to enter under the sheet of water.

The computation of yield, waste, etc., is generally done by engineers, and when the water-works man has written his observations, his work on that score is completed. Rainfall observations are also usually made by the man on the watershed as well as temperature readings, usually maximum and minimum daily, and these are often valuable as records for cases in court. Most ordinary gages are of the old type, where the diameter of the circular gage is 14.85 in., making 100 oz. to 1 in. of rain. It would be an excellent idea if a second rain gage were provided on a number of watersheds, so that the rates of rainfall could be measured in heavy storms, not waiting until the morning of the ensuing day before the 24 hours rainfall is weighed. It is also a useful practise to measure the depth of snow on the ground at intervals during the winter, as well as to weigh the equivalent rainfall on the ground at the maximum, so as to know what to expect in case of a freshet in the spring thaws.

Aqueducts should be cleaned perhaps once a year or so, as otherwise the flow is apt to be impeded. The Sudbury aqueduct, about 50 years old, has been found to show what is called a seasonal coefficient of flow, the coefficient increasing in the winter and decreasing during the summer, and if the aqueduct is not cleaned for several years the general line of this seasonal coefficient slowly drops, so that the amount the aqueduct will permit to flow may vary to as low as 85 per cent of a full or 100 per cent flow.

The cutting of grass from the embankments, while sometimes done merely to conform to the neighborhood where trim grounds are the rule, is hardly necessary unless the grass pays for the cutting. Frequently such cutting is only a burden as its cost exceeds its value.

There are various works whose operation require the attention of numbers of men to operate. One of these is the separation of street wash or other surface pollution that it may not enter the water supply without previous filtering. On the Sudbury system the street wash of Natick and also of Marlborough is thus filtered through sand filters built from local

material. In the first case the wash is pumped onto the filter beds, by steam pumps, thence flowing into the water supply. Any water flowing without filtration which might occur during very heavy flows, should be dosed with chlorine before passing into the water supply. Where the necessary pumping can be accomplished by automatic electric pumps it is a considerable advantage. Filter beds may require an occasional " picking up " or " harrowing " to renew their original capacity. In severe winters some trouble may be occasioned by ice on the surface of the water in the beds, and it is sometimes necessary to break up or cut holes in the ice to permit a greater flow. Where any water is removed from the watershed, the one in charge should check all measurements of water so taken, also of any water from outside the watershed, to the end that the net yield may be figured with fair accuracy.

Another of the plants in operation on the Sudbury watershed is the power plant at Sudbury dam, which was built as an afterthought, or installed in the gatehouse nearly twenty years after the dam and gatehouse had been erected. This plant affords a remarkable example of conservation of head otherwise thrown away, and one which yields to the water-works system an annual net profit of over $15 000. All the current is sold to the Edison Company, and as the plant is run as a rule 15½ hours daily, covering their " peak load," it is worth considerably more than what is termed " dump load " which might be turned on or off at almost any hour. I will not detail the features of this plant, as that has been covered elsewhere, but merely suggest a good example to follow for such water-works managers as have considerable head to spare and a market for the resultant electric power. Very few men are required to run this plant, and it is an outstanding example of efficient municipal operation.

In many water-works systems the flow is directly into the mains, so that no adjustment of flow is required, but on the Sudbury system the flow has to be readjusted almost daily, as the receiving reservoir does not permit a large latitude as to fluctuation, and the amount pumped varies considerably. From previous experiment and observation, a known elevation at the head gates results in an approximately certain volume of water going down, corresponding to a known gate opening, consequently it is possible with a few trials to send down the exact amount required. In the case of a second aqueduct, it is required that 24 hours' supply be sent down in less than 15½ hours, i. e., 15½ hours in delivery for 24 hours' use in a reservoir of small capacity, so that care has to be taken that the " peak " of the flow shall not cause an overflow. As the water sent into the reservoir takes 3 hours to travel down from the source, a computation has to be made to prevent overflowing of reservoir. The water being taken out has to be assumed as being drawn at a uniform rate, which is not the case. However, practice in these matters makes errors rare. In covering a holiday or a Sunday, more assumptions have to be made, so that it is not an easy matter to adjust flows under such conditions.

The Metropolitan water is used raw and is presumably free from pollution. Probably the only danger is from bodies of animals or human beings drowned unknown to any one. Happily, so far as we are aware, this has never yet happened.

There are a number of minor points which I will not attempt to cover, such as gages, records, screening, etc., but I would refer to one condition which was brought about by those who built the Sudbury system for the city of Boston in 1875, when a 48-in. pipe was laid for nearly a mile under one of the reservoirs, and was not sufficiently covered to prevent it from floating when the pipe was emptied. When the second pipe was laid it was laid in solid ground outside the reservoir. The first pipe mentioned has floated but once, but such spots in any water-works systems are always a source of anxiety to those in charge. A pipe belonging to a small town which the Metropolitan Water Works supplies on the way to Boston unfortunately has a 14-in. suction pipe which passes under a pond for half a mile, and on three occasions this pipe has floated and broken, causing endless trouble and anxiety to those in charge, as the pond under which it passes is very far from being desirable as a water supply. In the case just mentioned the water was treated with chlorine and it seems now almost self-evident that any water supply where any possible contamination is likely to occur cannot dispense with some means of protection. The cost of a treatment at least of chlorine is so slight, and the escape from serious trouble so very important that the neglect of what might be termed an insurance to at least a limited extent can hardly be excused. There have been cases where, with a sewage plant located near a water supply, gates or pipes in the station have failed or the pumping machinery has broken down, and before relief could be obtained, the sewage has overflowed into the adjacent storage basin. I think it is clear that the officials in charge of watersheds should always be on the alert for any contingency which may involve danger to the water supply, and that when any particular trouble is possible of occurrence at long intervals, that is the very matter for which the official should be on the watch. He should never sleep.

Discussion.

Mr. J. M. Diven.* There is no doubt about the desirability of white pine as a timber, but unfortunately in some parts of the country, in New York at least, white pines have been attacked by the " white pine blister " and even mature pines have been destroyed. This trouble has been so great that the New York State Conservation Commission advise against setting out white pines and are not raising any more seedlings for distribution. About ten years ago the speaker set out 240 000 trees on the watershed at Troy. N. Y.; the young trees — seedlings mostly — were

* Secretary, American Water Works Association.

procured from the state and were supplied at nominal cost. While it may be that the " blister " has not reached New England States, it should be studied and have careful consideration in planning for forestization of watersheds, for sooner or later the blight is sure to reach there unless a remedy for it is found. Currant and gooseberry bushes are now thought to cause or spread the blister and they should be destroyed wherever white pines have been planted. I think they are considered dangerous for a distance of half a mile from the pines.

At Troy, red and Scotch pines were planted mostly and they have been very successful; many trees are now twenty to thirty feet high and all look healthy and vigorous. Some Norway spruce were planted: these have very heavy foliage and spread near the ground, thus forming a good protection from dust and other wind-driven dirt where there is a highway near the reservoir. At Troy these were planted too near the reservoir bank and did not do as well as the pines.

As a watershed protection the coniferous trees are to be preferred to the deciduous varieties, as being evergreen they afford winter protection more than the bare trunks and limbs of the deciduous ones. Many hard woods would be valuable as timber, though mostly of slower growth than the pines. Nut trees, though valuable for both crop and timber, should be avoided on account of the temptation to the small boy to trespass and violate all sanitary rules.

Mr. Winslow. At Framingham we have taken away all the bushes of that sort — currant and gooseberry — from the vicinity of those trees.

Mr. Albert L. Sawyer.* I do not know that I have anything new to offer from what I have said many times before. We are still taking pretty good care of our watershed, and we have practically stopped the boating, fishing, and everything of that sort.

We have been setting out more or less trees for the last two years, — white pine and Norway spruce, obtained from the Forestry Department, — and they have come along very well indeed. In regard to the boating and fishing, the only thing I could say would be that if you want to stop these things you have to keep consistently and constantly at it, and if you do that it has been our experience in Haverhill that you will get the results you are aiming at.

* Water Registrar, Haverhill, Mass.

WORCESTER'S RESERVOIRS, PRESENT AND PROPOSED.

BY GEORGE W. BATCHELDER.*

[*Read September 19, 1923.*]

The water supply of Worcester is collected in nine impounding reservoirs on the hills of Holden, Leicester, and Paxton to the west of the city and furnish a gravity pressure at City Hall of 100 lb. on the low service and 145 lb. on the high service system.

The various steps taken in the development of the reservoir system began with the construction of Lynde Brook reservoir which was completed in 1867.

Lynde Brook dam gave way in March, 1876, and the water rushed down the valley into the Blackstone River causing large property damage but no loss of life.

Water was pumped to the city from Coes reservoir while the dam was reconstructed, which work was completed in 1877.

In 1883 the city constructed a reservoir in Holden called Tatnuck Brook No. 1, this beginning its present low service system. In 1892 this dam was raised ten feet.

In 1895 the high service system became inadequate, so the water of Kettle Brook was taken and carried across to Lynde Brook through a thirty-inch cast-iron pipe. On this system four reservoirs were constructed.

Kettle Brook No. 1 in 1896
Kettle Brook No. 2 in 1903
Kettle Brook No. 3 in 1902
Kettle Brook No. 4 in 1904

On the Tatnuck Brook system there was constructed in 1901 a new reservoir called Tatnuck Brook No. 2. For several years after this no reservoir building was carried on, but in 1911 a long, dry period made it necessary to secure more water. The city, therefore, availed itself of the privilege reserved in the original legislative act allowing the Metropolitan Water Board to take various watersheds tributary to the present Wachusett reservoir and providing that Worcester should be allowed to take for its use what is known as the Asnebumskit watershed. On this watershed there was completed in 1913 Kendall reservoir, and there is now being constructed Pine Hill reservoir.

The water from this shed will be stored in Pine Hill and Kendall reservoirs; part of it will flow from Pine Hill reservoir through an open

* Water Commissioner, Worcester, Mass.

channel about ½ mi. long to the Asnebumskit Head Works, a small reservoir, gatehouse and spillway where water is diverted from the original Asnebumskit brook through a concrete canal 2 700 ft. long to Kendall reservoir. From this reservoir the water is carried through a concrete conduit passing through and under the divide between the two watersheds. This conduit is 1 200 ft. long and 22 ft. under the surface at the deepest part, ending at the discharge pool from which point it flows through an open channel to Tatnuck Brook Res. No. 1, thence to Tatnuck Brook Res. No. 2, from which place it is conveyed to the city in cast-iron mains.

The reservoirs are in two groups, the high service system beginning at Lynde Brook reservoir, from which point all high service water is distributed to the city, and flowing by gravity into this reservoir are the waters of Kettle Brook reservoirs Nos. 1, 2, 3, and 4. The low service reservoirs are located in the manner previously explained. In addition there was constructed in 1895, Parsons low service distributing reservoir located at the same level as Tatnuck Brook Res. No. 2, and supplying a very small part of the low service draft.

The size, area, elevation, storage capacity, and drainage area of the various reservoirs are given in this table:

HIGH SERVICE.

Name.	Area. Acres.	Elevation.	Storage Capacity. Mil. Gal.	Drainage Area. Sq. Mi.
Lynde Brook	132	823	715	2.921
Kettle Brook No. 1	15	845	19	4.098
Kettle Brook No. 2	30.36	988	127	
Kettle Brook No. 3	37.41	1 040	152	
Kettle Brook No. 4	118.61	1 085	513	

LOW SERVICE.

Name.	Area. Acres.	Elevation.	Storage Capacity. Mil. Gal.	Drainage Area. Sq. Mi.
Tatnuck Brook No. 2	52.63	719	257	5.231
Tatnuck Brook No. 1	130	751	729	
Parsons Res.	2.42	719	10	
Kendall	171.82	814	800	2.451
Pine Hill	461	910	3 000	6.899

Upon the completion of Pine Hill dam and reservoir the present watersheds of Worcester will have become fully developed so far as present plans are concerned. Extensive studies have been made of watersheds adjacent to the city to determine the best place for the city to go for a future supply when it becomes necessary.

The available new sources of supply as taken from the last reports are:

Name.	Drainage Area. Sq. Mi.	Approximate Yield. Mil. Gal. Per Day.
Quinapoxet Pond	17.4	10–13
Ware River at East Hubbardston	9.8	8.5
Ware River above Barre Falls	56.1	50
Long Pond, Rutland	7.0	5–7
Turkey Hill Brook	8.9	8
Sugden Reservoir	5.9	5
Stiles Reservoir and Cedar Meadow Pond	7.9	6–8
Seven Mile River above Hillville	7.8	7
Five Mile River at Lake Lashaway	24.7	10–20

The care of the reservoirs is delegated to a foreman who employs during the summer season about fifteen men whose duties consist of cleaning the shores, cutting brush, trees, and general maintenance work. Forestry has been carried on extensively on the watershed areas owned by the city; hundreds of thousands of white pine trees have been planted, and in the main are in excellent condition. Lumbering has also been carried on in a large scale, mature trees have been cut, sawed by the department, using its own men and sawmill, and the product sold. Thousands of cords of wood have been cut within the last two years, much of it delivered to the schoolhouses and the balance sold to various parties.

Worcester furnishes ice water at a large number of public drinking fountains. The last year this ice was bought when prices were 15 cents per 100 lb.; the bills amounted to approximately three thousand dollars per year. The city has for several years been cutting ice for this purpose from one of its reservoirs and putting it in the fountains with its own men and truck. The cost of this work, including every item and 20 per cent annual depreciation on the truck, has never amounted to more than $900.

Three high service cast-iron supply lines run from Lynde Brook reservoir coming together at Webster Square within two miles of City Hall. They are 36 in., 24 in., and 20 in. in size and have sufficient carrying capacity to deliver water at Webster Square without frictional loss. At Webster Square near where the three lines are brought together they again divide into a 30-in. line running to the westerly part of the city and a 16-in. running to the easterly section, which will be shortly reinforced by a 30-in. line.

The low service supply lines are of cast iron, a 48-in. reduced to 42-in. runs within the 1½-mi. circle, this line is paralleled by a 30-in. reduced to 24-in. From Parsons reservoir on the south there runs a 40-in. pipe which crosses the Common in the rear of City Hall, 36-in. at that point and runs that size through most of the congested value district. A gate is closed on this pipe line near Parsons reservoir and is not opened except in case of emergency. During Worcester's most serious series of fires, when twenty-one bell alarms came in during the early morning and day of January 19, 1921, this gate was opened and a low service pressure of 100 lb.

was maintained through the period of heaviest draft. The high pressure system was never lowered below 112 lb., notwithstanding the fact that when the ruins cooled sufficiently so an inspection could be made, a 6-in. sprinkler connection was found broken completely off.

Just a word in closing about Worcester's system of hydrant inspection. During the summer season, hydrants are frequently gone over for the purpose of flushing and for other reasons. When winter comes, this is naturally discontinued and a systematic system of inspection begins. All hydrants in the business district are inspected every two days and those in the residential district every four days. Records of these inspections are kept on a card index system, reports turned in every afternoon and anything found out of good condition is at once remedied.

FILTRATION OF BURLINGTON'S WATER SUPPLY.

BY O. A. CANNING.*

[*Read September 18, 1923.*]

Since Lake Champlain has served Burlington as a source of water supply, many changes have been put in force in order to keep abreast of modern methods of sanitation.

At first raw water was pumped from near the dock. This was found unsatisfactory, and an intake pipe twenty-four inches in diameter was laid, extending two miles westward from the present site of the filtration plant. The water obtained in this manner was likewise distributed through the city mains unfiltered. This condition prevailed from 1894 to 1908. From 1904 to 1908 there were 151 cases of typhoid fever reported.

The State Board of Health, aware that the source of supply was polluted, saw the necessity of filtration, and as a result condemned the lake water as unfit for drinking purposes.

Following this action, filtration of water was begun April 15, 1908, and, for the time being, seemed to halt the spread of the disease; but it was soon proven conclusively that more drastic methods of treatment were necessary. This treatment was continued from 1908 to 1910 and 29 cases of typhoid fever were reported during the period.

In April, 1910, several changes in operation were made, the most important of which was the adoption of a method by which water was treated with hypochlorite of lime. This method was recommended to the superintendent by Hering & Fuller and consisted of dissolving the aluminum sulphate and hypochlorite of lime in one solution, which was applied to the raw lake water as it entered the coagulating basin and allowed to mix for one hour before going to the filter beds. The results were then thought to be satisfactory as the following table shows:

December, 1909 (bleach not used).	
Bacteria in raw water per c.c.	1 072
Bacteria in filtered water per c.c.	62
Efficiency	92 per cent
December, 1910 (bleach used).	
Bacteria in raw water per c.c.	732
Bacteria in filtered water per c.c.	6
Efficiency	95 per cent

The plant removed on an average 95 per cent of the bacteria from the lake water.

In 1911 the general method of operating the plant was completely

* Engineer in Charge, Burlington, Vermont.

modernized. During that year seven cases of typhoid were reported, but six were known to have originated outside of the city.

In 1912 there were	4 cases	
1913	2 cases	(originated outside)
1914	33 cases	(due to milk)
1915	27 cases	(due to milk)
1916	5 cases	
1917	9 cases	
1918	9 cases	
1919	4 cases	(carrier in hotel)
1920	18 cases	(originated outside)
1921	7 cases	
1922	1 case	

In 1921 (November) the last improvement was made. This consisted of installing two Wallace & Tiernan chlorine machines. In this process chlorine is used instead of hypochlorite of lime and up to the present time is proving very satisfactory. We are using 5 lbs. of chlorine to $2\frac{1}{2}$ mil. gal. of water and 1.10 grains of sulphate of alumina per gal.

Following these changes most gratifying results were noted, and much credit for present efficiency of 100 per cent is due to the untiring efforts of Mr. C. P. Moat of the State Laboratory and to Mr. C. H. Jones, ex-Water Commissioner.

Discussion.

Mr. J. M. Diven.* It may be interesting to ask what was the proportion of B. coli in the raw water; whether it was great or not?

Mr. Canning. Well, I think I should have to ask Mr. Moat to answer that question, because I am not a chemist.

Mr. Diven. You do not test for gas producers?

Mr. Canning. Yes, we do.

Mr. Diven. About how do they run?

Mr. Canning. I do not think they average more than one out of twenty in our filtered water. The lake water has coli all the time. We always have gas producers in the lake water; we very seldom get one without.

Mr. M. N. Baker.† When I entered the University of Vermont in 1882 one of the first things I heard about the Burlington water supply was words of caution from the President of the University, who, in accordance with his annual custom, gave good advice to the students about things they should do and should not do. One of his warnings was to be careful about drinking the lake water " until we got used to it."

Some time before the Burlington filter plant was built, I was invited by the city authorities to make a report on the character of the water

* Secretary, American Water Works Association.

† Associate Editor, *Engineering News-Record*.

supply. I dug back through the city reports, and compiled the typhoid statistics for Burlington from an early date up to the time of that report. The showing was rather bad — not as bad as for some other cities of the country, and the indications did not all point to the water supply as the source of the typhoid and of diarrheal diseases. Subsequently the late Prof. W. T. Sedgwick made a bacterial study of the supply, and later on the events occurred which have been so well presented in the paper. Many of the data in my Burlington report were embodied in a paper read before this Association, published in the JOURNAL in June, 1906.

Undoubtedly Burlington suffered for many years from the effect of doing the thing that years ago was so common throughout the United States — discharging sewage into the body of water from which its water supply was taken; and the extension of the intake did not eliminate or entirely prevent water-borne typhoid.

Happily now, Burlington, as the figures you have listened to indicate, is one of a large and growing class of cities in the United States where typhoid has been virtually eliminated. Such typhoid as remains in this city, and in other cities, we all feel thankful as water-works men, is rarely due to the water supply.

MR. R. W. WIGMORE.* I would like to ask if some one can give the cost of chlorinating water?

MR. GILBERT H. PRATT.† To answer the gentleman's question, the cost of the chlorine itself per million gallons varies somewhat with the quality of the water; but as a general average figure, about 50 cents to 60 cents per million gallons is a conservative figure.

Taking the case of Mr. Canning, he said he used about 5 lb. to 2 500 000 gal., which is only 2 lb. per million gallons. Of course I do not know just what their contract for chlorine is, but if they will take their contract price for chlorine plus freight, they will be able to figure their chlorine cost, which would be lower than the figure given, inasmuch as they only require a low dosage treating filtered water.

The first cost is another variable depending on the conditions, but for a round figure, let us say the minimum cost would be $600 per unit, and the maximum cost, according to whether you were working against pressure, as high as $1 500 or $1 600 per unit. By figuring depreciation at 20 per cent you can get your annual charge.

MR. WIGMORE. I might say, Mr. President, that I have an idea, from correspondence I have had with a firm, of the cost of installing. What I wanted to get at was the annual cost of maintenance, covering the cost of the chlorine and the incidental cost of operation. I realize that this cost might differ in certain cases, but the general annual cost of maintenance of this plant per million gallons, is what I was after.

PRESIDENT SANDERS. Will you tell us, Mr. Canning, at what point you apply chlorine to the water?

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* Commissioner of Water and Sewage, St. John, N. B.

† New England Representative, Wallace & Tiernan Company.

MR. CANNING. We apply the chlorine to the suction of the pump that pumps the water into the reservoir. Is that what you mean?

PRESIDENT SANDERS. Yes. Did you state what the capacity of your reservoir was?

MR. CANNING. I did not; but I can. We have two reservoirs. One has a capacity of 4 000 000, the other 3 000 000 gal., a total of 7 000 000 gal. which we have for reserve on the hill. Our water is not all pumped direct to the reservoir; it is pumped into the mains and the overflow goes to the reservoir.

PRESIDENT SANDERS. Do you have to pump 24 hours out of the day?

MR. CANNING. No, we do not. At different times of the year it varies a little. At the present time I think we are running about 16 hours out of the 24. Our capacity is about 2 500 000 gal. in 24 hours, and our chlorine machine is set for 5 lb. per 24 hours' run.

PRESIDENT SANDERS. What is the capacity of the pumps?

MR. CANNING. Two and one-half million gallons in 24 hours, that is, a little over 1 600 gal. a minute.

PRESIDENT SANDERS. Do you have more than one pump?

MR. CANNING. Yes. Each one has that capacity.

PRESIDENT SANDERS. Do you ever run both pumps together?

MR. CANNING. We never have. We just use the second one as an auxiliary.

PRESIDENT SANDERS. Then, you have a very constant use of the water, so that you can figure right down to a fine point just the amount of chlorine that you use in the water?

MR. CANNING. Yes.

PRESIDENT SANDERS. You do not have any variable amount?

MR. CANNING. Practically the same. It is the same from day to day unless we change the controller arm. We always run it practically the same; we do not vary it more than perhaps a half pound, or something like that.

MR. DIVEN. I think the gentleman from St. John can easily work out the cost of the chlorine and the original cost of the plant, and the depreciation. But with his gravity system he would probably have to have an expense which would not come in the pumping plant with its attendance. He probably would have to have an entirely separate force of men to look after the chlorination, make daily analyses and attend to the apparatus, which would not be required with the pumping plant.

MR. WIGMORE. That would depend on the location. If our chlorine plant was set at practically the source of supply, it would be necessary to have some attendant there; but if it was established along the line, say six miles from the general distribution, why, we have a man there now. So that it is just a question of where the proper location would be.

MR. PRATT. Along that line which Mr. Diven raises, I would like to raise one point, if I may. That is, with the automatic equipment, which

would be the type to use in the case Mr. Wigmore is speaking of, it would not necessitate constant attendance, but it would require at least a daily inspection. Of course the apparatus would automatically vary the flow of gas as the flow of water varied in the main. So that it would really be the same old question that anything automatic has got to be looked after, and it would be a case of where somebody would go around every day and inspect it.

I just thought I would correct any possible impression there might be that it would require three 8-hr. shifts, or anything of that kind, to watch it.

MR. CALEB M. SAVILLE.* If I tell what we do in Hartford about this matter, perhaps it will clarify the situation a little and possibly give the gentleman some light on the subject.

We have a gravity supply, and while we have filters and do not use much chlorine we do use enough to keep the gas machine turning over, as it were, for use should there be an emergency and the filters were put out of use.

We have a filtered water basin which has perhaps a head of 25 ft. on that portion of the pipe where a Venturi meter is located. Right at that point we have a chlorine gas house in which are located both an automatic device and a manually-operated device, so that if anything is wrong with the automatic machine the manually-operated one would be in service. Attached to these are four cylinders of chlorine gas in service all the time. We put in from one-tenth to two-tenths of a part per million — just enough to keep the machine in service. A man goes to this plant at least once each day, among his other duties, usually twice each day, — once in the morning and once in the afternoon, — to see that everything is working all right. That is all the attendance that is required.

Of course the amount of chlorine that is put in is shown by the register and the amount of water that is passed through is shown on the Venturi meter. The chlorine gas cylinders are set on scales, which are read every day and the amount of chlorine that has gone in, is thus known and checked against the amount which the automatic register shows.

Taking what the gentleman said about the Burlington supply, — if I remember it correctly, — I think Mr. Pratt said that it would be about 30 cents for the chlorine per million gallons pumped. That is for the chlorine inself. Mr. Pratt, I think, also gave a maximum figure of something like $1 500 or $1 600 for the cost of the plant. If you write that off in five years, there is about $300 a year to write off every year for the plant. Dividing the $300 per year by the total million gallons that is used per year gives you the cost per million gallons in plant. Then if you put a man on there and let him go around, I suppose you would allow an hour or two hours of his time on each day for his attention to the chlorine. Those

* Chief Engineer, Board of Water Commissioners, Hartford, Conn.

added to the cost of the chlorine used will give fairly near the cost per million gallons for your plant.

Does that answer your question?

MR. WIGMORE. Yes, sir. Thank you very much.

MR. BAKER. I might say that many years ago there was installed, up by the reservoir — apparently so long ago that those now in charge of the water works have forgotten it — a high service pump driven by the hydraulic pressure in the main delivering the water into the reservoir. This pump delivered water to a tank at a higher elevation, supplying a limited high service area. It was an interesting and unique piece of automatic high service pumping machinery. The installation was described in *Engineering News*, October 1, 1887.

ELIMINATING WATER HAMMER FROM A HIGH-PRESSURE REGULATING VALVE.

BY SYDNEY LEE RUGGLES.*

First a bit of history. The Barre Water Company, a private corporation operating under the "Goodhue" patents, was organized in 1886 to supply water for domestic, sanitary, and fire-protection purposes to the city of Barre, Vermont, and the system was installed in 1887–1889. The supply was taken from the Jail Branch of the Winooski River by the construction of an intake dam about two and one-half miles from the city, and at an elevation approximately three hundred and forty feet above the business portion. Trouble was soon experienced from typhoid and other intestinal diseases due to the fact that the considerable town of East Barre was situated not far above the intake dam. The State Board of Health condemned the source of supply and it was abandoned as soon as possible.

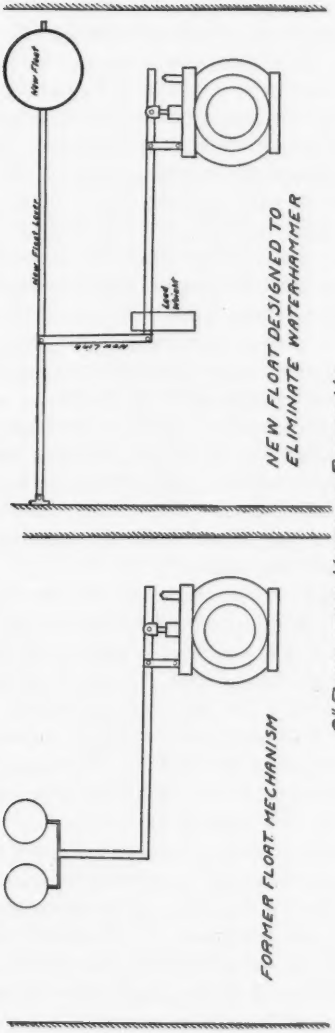
In 1897-8 a new supply known as the Bolster was developed by a main running along the Barre-Williamstown road which tapped two brooks, but this was soon found inadequate and the Water Company resorted to pumping from the Stevens Branch of the Winooski, which was nearly as bad as the Jail Branch, since it came through the village of Williamstown. The city took over the plant in 1898 and immediately extended the Bolster main to tap a third brook in the town of Williamstown known as the Martin Brook. Even this did not furnish an adequate supply and pumping from the Stevens Branch was continued.

Acting under the advice of Freeman C. Coffin and other engineers, the city constructed a line of pipe about three miles long from a point on the pipe below the old dam of the original Barre Water Company on the Jail Branch to a mill site on a branch of this stream in the town of Orange, and by the construction of a gravel filter used this supply for six years.

In 1910 a storage reservoir of about forty million gallons was constructed just below this milldam from which the present so-called Orange Supply System is taken.

As the new Orange Reservoir is about five hundred and eighty-five feet above the city, and the old one eight feet higher, the resulting pressure head if piped directly to the city would be about two hundred and fifty pounds, an almost prohibitive figure. Accordingly the original 16-in. line of the old Barre Water Company was cut just below their dam and a chamber which we know as the "Reducing Chamber" built over the pipe. To this was piped the lower end of the Orange extension which was reduced from a 24-in. pipe at the dam to an 8-in., and an 8-in. regulating valve

* City Engineer and Superintendent, Water Department, Barre, Vermont.



8" REGULATING VALVE AT BARRE, VT

installed at its entrance to the chamber. The original valve as designed by Mr. Coffin was a simple flap valve operated by a large float and a walking beam mechanism. This was replaced in succession by balanced valves of three different types, none of which have been satisfactory. The size of the chamber itself is much too small, being 6 ft. 6 in. by 9 ft. in area and about 5 ft. 6 in. deep. This inadequate area gives such a rapid fluctuation in water level that the valve is constantly working. Successive superintendents have pointed out this defect and recommended a larger chamber, but the City Council has as regularly turned down the project.

The valve is working under a pressure head of 272 ft. on one side and 3 ft. on the other and has to stop or start three miles of water. The lever arm of the float operating the valve was about three and one-half feet and the valve closed with a rise in the water level of about six inches. Under this combination of circumstances severe water hammer was to be expected and was realized. Sometimes as many as seventy-five leaks in a season developed between the valve and the reservoir, and in the spring when the frost came out of the ground the repair gang would have from two weeks' to a month's work recalking blown joints.

Apparently the only method used by previous superintendents to relieve the water hammer was to adjust the stop bolt on the regulating valve so that the valve could not completely close and thus cut down the water hammer to a safe degree. This meant, however, that at night a large amount of water was wasted over the spillway in the chamber, a dangerous loss in time of low water.

On coming to Barre three years ago to take the supervision of the Water Department, I was introduced to the Reducing Chamber by the retiring superintendent, who said that it was one of the nightmares of our position. He explained this method of control, which worked very well (aside from the waste of water) for short intervals. But a few months' bumping of the check bolt would wear it down, and soon reports of a leak or two in the road would be brought in. Overnight these would develop into half a dozen. We would then adjust the stop again and would have comparative peace for a few short weeks.

Having been a teacher for ten years before going into practice, I began to put my training in mechanics to work after some months' experience with this chamber. In the first place I recommended the installation of a relief valve which was purchased and installed two years ago. This cut down the effect of the water hammer, but did not strike at the source. The water in the pipe would often pulsate more or less regularly and the relief valve would blow off every few seconds.

Then I turned attention to the regulating valve and worked out a new float control. I ordered a new float 12 in. in diameter and 24 in. long and a new lever of such length that when hinged on the side of the chamber opposite the regulating valve the float at the other end would nearly reach the opposite wall. I removed the original small floats, but kept the original

lever. A little calculation of the lever arms showed where to drill the new lever arm so that a link hinged at this hole and attached to the end of the old float lever would multiply the lever ratio by about three and one-half, which was the ratio between the available rise and fall of the new float and that of the original one. This meant that the water had to rise nearly two feet to close the valve instead of about six inches, and solved the problem, as it now closes so slowly that nearly all water hammer is eliminated.

There was still one difficulty to be remedied, however. Although the regulating valve was of the balanced type with water admitted at both top and bottom at the same time to equalize the pressure, there seemed to be an unbalance at a certain point in closing. When this point was reached the valve closed suddenly with a decided kick, the pressure jumping instantaneously sometimes as much as sixty pounds. As observation showed that this kicked the lower or original lever upward, I hung about two hundred pounds of lead on the outer end next to the link connecting the two levers, eliminating that kick effectually.

The proof of the pudding? In two years we have had six small leaks. When the frost came out of the ground this last spring three small leaks were evident in three miles of pipe. I sent up three men who dug up and recalked all three leaks in one day, where formerly it would sometimes take a month each spring to repair damages.

THE CAUSE AND EFFECT OF RANGE-BOILER EXPLOSIONS.

WILLIAM A. BRADFORD.

[*Read November 13, 1923.*]

I had the honor, as well as the pleasure, of speaking before your Association in December, 1915, and February, 1916, on this same subject. At that time I tried to demonstrate by the use of lantern slides, and the talk which I gave, the probable cause and effect of range-boiler explosions. I also gave a practical demonstration of the unreliability of many of the so-called "water relief valves," which were then upon the market, when placed in practical use, also demonstrating that they were not dependable when an emergency arose.

One of the other features, and what to me seemed a very important one at that time, was the necessity of the enactment of certain legislation which would require the manufacturers of range boilers to meet the requirements and conditions, as well as the strength and capacities, for which their boilers were sold. This also applied to tanks and other vessels which were to be used for the storage of hot water.

At that time boilers were being sold to the plumbers, and installed by them, the capacity of which was anywhere from 10 to 25 per cent less in actual test than the manufacturer's stated capacity of the boiler. The strength of the boiler varied anywhere from 15 to 40 per cent less than the indicated tested strength which was generally stamped upon the side of the boiler by the manufacturer.

I had already introduced in the Legislature a bill to try to remedy the existing conditions, and asked for the support of the members of your Association for the passage of the bill. The bill did not pass that year, but I pursued the same policy and introduced the bill again, and it was passed in the succeeding year. The passage of this bill was not a panacea for all the existing conditions, but it was the first step in the right direction, and carried such powers of enforcement with it that the inspectors of plumbing within their respective cities and towns shall cause the provisions of the act to be enforced. Many of the inspectors in various cities took cognizance of this fact and require that the plumbers in the installation of boilers for the storage of hot water live up to it in its entirety. I fear, however, that in many other cities and towns the inspectors have failed to take advantage of what was useful and necessary legislation.

It would seem, Mr. President, that this is the psychological time to point out to the members of your Association, especially those who reside in Massachusetts, that they could be of great service to the public, municipalities, and the plumbers as well, by striving to have this law strictly enforced in the communities in which they live.

I have no desire to use valuable time on those things which are past, but I do wish to point out briefly to you exactly what the law does and could accomplish with closer coöperation. The following is the old and also the amended law.

MASSACHUSETTS BOILER LAW

Arrangement of the Old and the *Amended or Revised Massachusetts Boiler Law

Old Law General Acts of 1916, Chapter 154.
Amendment General Acts of 1917, Chapter 39.

Acts Relative to the Marking, Sale and Installation of Range Boilers.

Be it enacted, etc., as follows:

Section 1. No range boiler shall be sold or offered for sale in this commonwealth, unless its capacity is plainly marked thereon in terms of Massachusetts standard liquid measure, together with the maker's business name, in such manner that it may easily be identified.

Section 2. No copper, iron or steel pressure range boiler, whether plain or galvanized, or other vessel or tank in which water is to be heated under pressure, shall be sold or offered for sale in this commonwealth without having stamped thereon the maker's guarantee that it has been tested to not less than two hundred pounds hydraulic *or hydrostatic* pressure to the square inch, together with the maximum working pressure at which it may be installed. And no such boiler, or other vessel or tank in which water is to be heated under pressure, shall be installed if the working pressure is greater than forty-two and one-half percent of the guaranteed test pressure marked thereon by the maker.

Section 3. Any person who sells or offers or exposes for sale any range boiler which is not marked or stamped as provided in the preceding sections, or which is falsely marked as having a capacity which is greater by seven and one-half percent than its true capacity, or who marks or causes the same to be marked with such false capacity, shall be punished by a fine not exceeding fifty dollars for each offence. The inspectors of *plumbing within their respective cities and towns shall cause the provisions of this act to be enforced.*

Section 4. This act shall not apply to the sale or offering for sale of installed range boilers or to the sale or offering for sale of range boilers as junk.

Section 5. This act shall take effect on the first day of July, nineteen hundred and seventeen. (Approved March 1, 1917.)

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*Author's Note: This has been arranged to show both the old and revised law. The part in italics refers to the part amended.

Various tests and experiments were made by me, as shown in Table 1, to determine if possible the variances between the rated and the actual strength and capacity of many of the standard makes of both copper and galvanized range boilers.

In Fig. 1 the two boilers at the right clearly indicate the variances in strength and capacity of range boilers of both copper and galvanized iron previous to the enactment of the Massachusetts Boiler Law (General Acts of 1916, Chap. 154). The figures shown on the boilers were charted after making the tests previously referred to, and indicate that copper and galvanized-iron boilers were then being sold of a capacity of from 15 to 25 per

TABLE I.

Number of Test Maker of Boiler Style	No. 1 Dahlquist Competition	No. 2 Dahlquist Full 30	No. 8 Dahlquist Guaranteed	No. 3 E. B. Badger	No. 4 Hayes Mfg.Co. Modern	No. 5 Galv.	No. 6 Moriarty	No. 7 Star Regular
Number of Test	No. 1	No. 2	No. 8	No. 3	No. 4	No. 5	No. 6	No. 7
Weight of boiler empty	42 lbs.	54 lbs.	56 lbs.	44.5 lbs.	49.5 lbs.	64.5 lbs.	59 lbs.	25 lbs.
Weight of boiler full of water	252.25 "	309.0 "	316.0 "	288.5 "	300.0 "	286.5 "	303.0 "	283 "
Weight of test equipment	58.00 "	69.5 "	72.25 "	61.0 "	66.0 "	81.25 "	76.0 "	41 "
Weight of water in boiler—Net	194.25 "	239.5 "	243.75 "	227.5 "	234.0 "	205.25 "	227.0 "	242 "
Temperature of water at test	44° F.	44° F.	43° F.	44° F.	44° F.	44° F.	43° F.	43° F.
Rated capacity of boiler	30 gal.	30 gal.	30 gal.	30 gal.	30 gal.	30 gal.	30 gal.	30 gal.
Actual capacity in gallons by weight	23.45 "	28.85 "	29.24 "	27.29 "	28.2 "	24.72 "	27.35 "	29.15 "
Boiler minus rated capacity	6.55 "	1.15 "	.76 "	2.71 "	1.8 "	5.28 "	2.65 "	.85 "
Actual weight of boiler—stripped	42 lbs.	54 lbs.	56 lbs.	44.5 lbs.	49.5 lbs.	64.5 lbs.	59 lbs.	25 lbs.
Actual outside circumference	35.125 in.	37.75 in.	37.5 in.	37.25 in.	27.75 in.	36.25 in.	36.75 in.	37.5 in.
Actual height of straight side	54 "	57⅝ "	59 "	54 "	54⅜ "	58 "	56 "	59.5 "
Actual height of dome top	3¼ "	3½ "	4½ "	5 "	5 "	1½ "	4½ "	1½ "
Form of top head	Flat oval dome	Round dome	High round dome	Round oval	Enlarged round dome	Flat oval dome	High round dome	Flat dome
Form of bottom head	Flat	Flat	Bulged out	Bulged 1 in.	Bulged out	Dented in	Flat	Flat
Circumference equal to diameter of	11.2 in.	12 in.	11⅞ in.	11⅞ in.	12 in.	11 9/16 in.		11⅞ in.
Theoretical capacity (As per above measures)	26.46 gal.	29.38 gal.	30.5 gal.	27.765 gal.	29 gal.	25.52 gal.	30 gal.	
Capacity by drawn off measure by Sealer of Weights & Measures		28.89 "	29.88 "					
Factor used by weight—1 gal. =	8.3 lbs.	8.3 lbs.	8.3 lbs.	8.3 lbs.	8.3 lbs.	8.3 lbs.	8.3 lbs.	8.3 lbs.
Factor used by capacity—1 gal. =	231 cu. in.	231 cu. in.	231 cu. in.	231 cu. in.	231 cu. in.	231 cu. in.	231 cu. in.	231 cu. in.
Actual weight of one gallon by Sealer of Weights & Measures	8 lbs. 5 oz. 2 dr. 19 gr.							
Expressed decimally, lbs. per gal.	8.323 lbs.							
Allowance by Tolerance for 30 gal.	27 cu. in.							

cent less than that for which they were rated, and that their tested strength was from 10 to 40 per cent less than that stamped or marked by the manufacturer on the side of the boiler.

The boiler at the left shows clearly, in an enlarged form, how the boilers must be marked now to comply with the law, and if a boiler is sold for a 30-gal. boiler it must hold within $7\frac{1}{2}$ per cent of its rated capacity as marked, or exactly 27.75 gal. If the boiler is rated as a 200-lb. test boiler it must be stamped that in effect, and guaranteed to work under a constant pressure of $42\frac{1}{2}$ per cent of its tested strength, which would mean that a boiler so marked would be suitable for use under 85 lb. working pressure.

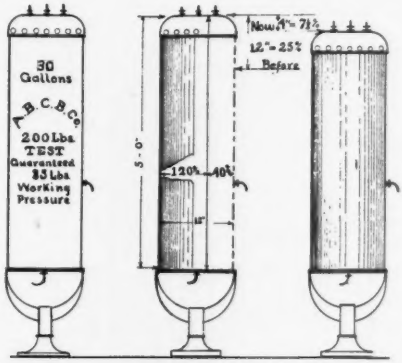

FIG. 1.

This seems like the logical time to make the line of demarcation between the type of installation which is called a " cistern pressure boiler " and the so-called " pressure system." The former is supplied from a tank in the attic from which it derives its head or force, the same tank acting as a receptacle for the expanding water in the boiler while under heat, or for the superfluous water caused by expansion.

In the latter, or pressure, system, the tank receives its supply of water direct from the city main through the service pipe and consequently is subject at all times to approximately the same pressure (less the difference in height) as exists in the main.

Fig. 2 illustrates, and affords as well, an opportunity to make a comparison between the two systems. In actual operation the principle is the same in both cases, except the difference in the higher elevation of the tank, reservoir, or standpipe shown at the extreme top right-hand corner of the drawing. This higher elevation creates additional pressure and the boiler which is supplied under this head of water must of necessity be of heavy construction, and is called a " pressure boiler." The elevation of the reservoir which is 200 ft. above the boiler is equal to approximately 86 lb. pressure per square inch.

The boiler shown at the left is supplied from a tank in the attic, or the upper part of the building. In former times this tank was called a cistern, and from this fact we derive the name of " cistern boiler " for this particular type of low-pressure range boiler. In this instance the cistern or tank is 25 ft. above the boiler, and the head of water is equal to a pressure of approximately 10.85 lb. per square inch.

We labor under the impression that water is a great conductor of heat. Nothing could be more erroneous. Water itself is a great insulator and nonconductor, but on account of the mobility of the molecules of which it is composed, circulation is easily set up and maintained when heat is

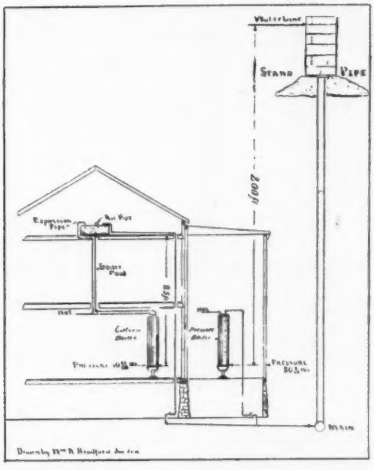

FIG. 2.

applied. Water, when heated, expands and becomes lighter, volume for volume, and it is due to the difference in density or specific gravity in two like columns of water, that it may be set in motion and circulation maintained.

Under a rising temperature from 60 degrees to 212 degrees, the boiling point of water at atmospheric pressure, a given quantity of water will expand approximately $1/25$ of its bulk. If the water is confined in a bent tube shaped like the letter " U," both sides being of equal length, and heat is applied near the lower portion of either tube, water will expand in one tube to a higher elevation, particularly on the side to which the heat is applied. If the original height of each column of water in the tube is 25 in., and the extreme temperature as stated above, was obtained, then the height of the water in one tube would be approximately 26 in. If a connecting tube is applied horizontally between the two perpendicular tubes, at the original height of the water before it was heated, then the water which is at

a higher level in one tube will flow through the connecting tube into the other tube and create the motive power or additional head which will start the circulation of water through both columns as a consequence of their having been thrown out of equilibrium. When small single tubes are used, in either a horizontal or perpendicular position, a partition called a diaphragm is generally arranged in the center of the tube to insure circulation and prevent confusion between the ascending and descending columns of water.

The principles involved in the circulation of water and other fluids when confined in vessels are clearly shown in Fig. 3, which illustrates a

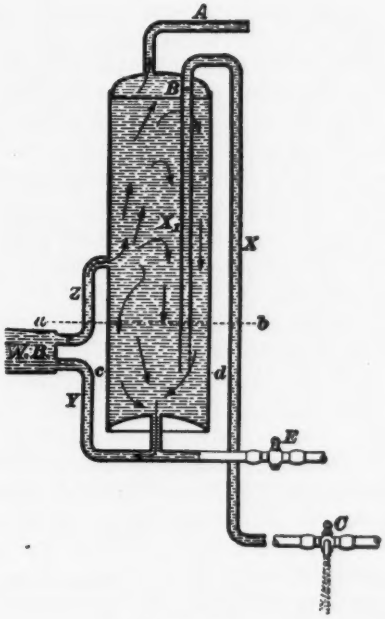

FIG. 3.

sectional view of a pressure boiler and the usual system of piping connected thereto. Note the cold-water service pipe X, and how it extends down into the boiler to a point about one foot from the bottom. This is the usual arrangement and shows that the pipe X outside of the boiler becomes the long leg of a siphon. When stop C is closed and water is allowed to escape through the waste hole, water is siphoned directly from the boiler and a vacuum is bound to occur in the boiler.

To prevent the formation of a vacuum a hole is made in pipe X at a point inside the boiler about six inches from the top. This is called a sniff hole, and is supposed to allow air to enter pipe X at point B and break or

relieve the vacuum. It can readily be seen that such relief cannot be obtained until the water at the top of the boiler has been reduced to the level of the sniff hole B, even though you open a faucet on the hot-water distributing pipe A. Should you not open a faucet on pipe line A, which would allow air to enter and further relieve the siphon, then the sniff hole is of no consequence and water will continue to siphon from the boiler through pipe X, wasting through the drainage hole in stop C, and create a more severe vacuum in the boiler. The same effect is obtained, only more quickly, when the water is shut off in the main and drained, or when, as very often happens, a street main or supply pipe suddenly breaks, unless due precautions are taken to prevent the formation of a vacuum in the boiler. The greater the vacuum in the boiler the more severe the collapse as a consequence of the atmospheric pressure being continuously in force at all points on the outside of the boiler. If a complete vacuum could be created inside the boiler, to crush it in the atmospheric pressure bearing on the outside of the boiler would be equal to approximately 15 lb. per square inch of exposed surface, hence the use of the vacuum valve.

Undoubtedly the vacuum valve was placed on the market earlier than the water relief valve. Carr's vacuum valve was probably in use 35 or 40 years ago. Other opinions to the contrary, I still believe that its proper location is attached to the cold-water feed pipe, directly over the top and as close to the boiler as possible.

To be of service a vacuum valve must operate instantaneously. The velocity with which air will enter a complete vacuum is equal to 1 320 ft. per second. This is 1.4 times faster than a stream of water would be discharged under the same pressure from a pipe of equal diameter. Vacuum valves, to be efficient, must be free from mechanical parts, springs, and so forth, and operate at the lowest possible pressure. Mechanical devices in vacuum valves, when used singly or when used in combination with a water relief valve, are partly the cause of their failure to operate when required to do so.

When a vacuum valve is required what could be simpler or more practical than the ordinary brass check valve? In the case of a top check or lifting check valve, the disc will be lifted from its seat under a very slight pressure. There might be some objection to this particular type of valve, as there is a possibility when the disc and seat are both of metal that they might cohere or adhere to each other. There is a possibility of residue collecting on the seat of the valve which would prevent it from closing tightly.

In the swing check valve I believe we have none of the objectionable features which I mentioned in connection with the top check valve. Furthermore, the valve could be arranged in a diagonal position so that the slightest amount of atmospheric pressure on the reverse side would cause the clapper to which the disc is attached to swing quickly inward, allowing the air to enter before a vacuum could be created. Moreover, for the purpose of determining whether the valve was in working order the disc could

be pushed from its seat by inserting anything of small diameter into the inlet end of the valve.

But, why all this worry, when for a few dollars more on the initial cost of the boiler, copper boilers can be obtained which are guaranteed against collapse, and for a more modest expenditure, a good grade galvanized-iron boiler may be used, which is not only noncollapsible, but on account of being built of heavier and stronger material, is better able to withstand the strain of excess internal pressure?

I have used a little more time than I intended in describing the cause and effect of a vacuum in and on range boilers, believing it would be of interest to the members of this Association, inasmuch as many of the complaints for damage to boilers from this cause are brought to your attention as superintendents of the water works in your respective towns and cities. Let us now turn to the two more dangerous conditions under which range boilers and other vessels in which hot water is stored under pressure have to operate, namely, excessive pressure and temperature.

Modern methods of living, and modernized plumbing, have brought about more insistent demands for instantaneous hot water, and the main idea to-day seems to be to produce these results by cutting down the storage capacity of the boiler and providing an excessive amount of energy in the heating agencies by substituting in place of the old cast-iron water front with its typical connections based on 50 sq. in. of heating surface for a 40-gal. boiler, brass water fronts and brass coils in the stove, auxiliary gas water heaters of intermittent and instantaneous types, tank heaters of both brass and iron excessive in size, and lastly, the introduction of brass coils into the fire pots of furnaces, steam and hot-water heaters, used for house-heating purposes.

The pressure system of hot-water supply is here to stay and we may as well recognize that fact. Modern sanitary conveniences require that the flow of hot water be equal to that of the cold. In order to accomplish this it is necessary that both hot and cold-water supplies be installed to work at approximately the same pressure. Hence the so-called " pressure system " of domestic hot-water supply. It has often been advocated that we return to the old method in which the boiler receives its supply from the cistern or tank in the attic at a much lower pressure, but the modern construction of buildings does not permit of doing this, and of course in high buildings, such as office buildings, and so forth, the pressure on the boiler would be approximately the same, whether supplied from the city main or from a tank at the top of the building.

On a pressure job, with all valves and faucets tight, the system is under a constant pressure equal to that in the cold-water service pipe. When a faucet of the compression type is opened the pressure is reduced; when closed, the system again returns to its normal pressure. The only relief for the expanding water from the boiler would be back into the main. Should anything prevent its egress, then an additional amount of pressure would be created within the system.

With a Doherty Self-Closing Bibb, when excess pressure was created, it would overcome the tension of the spring and force the disc from its seat, thereby relieving the pressure. I have in mind an actual occurrence where the range boiler was excessively heated, and the plumber condemned some faucets of this type because he claimed they leaked, when in reality they were only striving to relieve the excess pressure that had been generated in the domestic hot-water supply.

The Bashlin Bibb, although of the self-closing type, would afford no such relief as the one previously described on account of the fact that the greater the pressure generated in the system, the tighter the disc would be driven against the seat.

The Quick Closing Fuller Bibb would also act in the same manner. When the lever is released the ball is driven more tightly on to its seat because of the conical shape of the ball washer with the larger area on the pressure side.

The relative infrequence of explosions when we consider the multiplicity of copper pressure range boilers in use in this territory, is undoubtedly due, in part at least, to the following fact, namely, that it is very seldom a ball cock is absolutely tight. Assuming that there was an obstruction in the supply to the boiler on account of a check valve, or a pressure reducing valve, having been placed in line of same, or the pipe having become stopped or plugged up, I am confident that relief from additional pressure would be obtained through the ball cock, provided of course that there was one connected with some part of the plumbing system in the building or house. This statement should not be construed to mean that relief from excessive temperatures in the domestic or other hot-water systems could be obtained in the same way.

I carried on experiments and found that with a certain type of compression ball cock, with a 5-in. float under a hydraulic test, the cock would open at a 120 lb. pressure, and discharge exactly 227 grains of water, equal to 1 oz. avoirdupois. I tried this 10 times with the same result each time.

Substituting a 6-in. for the 5-in. float, it required 130 lb. pressure to overcome the resistance of the 6-in. float. This statement checks up with the fact that on one occasion a certain gas company, in making repairs, shut off the supply to the house without reducing or checking the heating of the range boiler, and as a consequence, hot water was drawn from the closet tank when it was flushed.

With a "Dececo" Rotary Ball Cock it was necessary to apply a pressure varying from a 140 to a 145-lb. before relief could be obtained when a 5-in. float was used on the ball cock. When a 6-in. float or ball was used on the same cock it required a 150-lb. pressure to overcome the flotation of the ball. This particular style of ball cock possesses the feature of closing more quickly than the other.

A plumber living in the vicinity of Boston who has given this matter

considerable study tries to arrange the piping in the building so that there will be a separate or independent supply to the range boiler, having the theory in mind which I have just described. Into the boiler feed supply he connects a branch pipe to supply the ball cock on the nearest closet tank, with no shut-off or other obstruction in either line.

That we all may have a better understanding of this subject I am trying to show the pro and con of every proposition. The ball cock, called the "Novelty," would not function in an emergency like those which I have previously described, because the seat is a movable, hollow tube, and when once seated on the disc of the ball cock, excess pressure on the supply side would have no effect upon it whatever.

On other occasions when I spoke to the members of your Association I stated my belief that the only panacea for the troubles about which we are talking would be a rigid supervision and inspection of all installation and piping in connection with this work. As briefly as possible I desire to show a few of the dangerous defects due to faulty construction and installation which I believe, had they been subject to inspection, would not have been permitted or used.

When a pressure water regulator, oftentimes called a pressure reducing valve, is used on the house supply or the cold-water supply leading to the range boiler there is absolutely no chance for the expanding water in the boiler to find relief. The accumulated pressure on the house side of the regulator is used as a motive power, functioning on a diaphragm of large diameter to overcome the initial pressure of the service pipe. Hence, the greater the pressure on the house side the tighter the valve will close. In a sense it becomes a check valve and prevents the outward flow of water, and consequently should never be used except in conjunction with a reliable water relief valve, especially with a closed or pressure system of hot water.

A subscriber to a trade paper writes, "Will you please advise me of the different methods now in use to prevent hot water from range boilers getting back into meters by expansion or by siphonage? I am quite familiar with putting a hole in the conducting tube, but that will not always overcome the difficulty. Suppose the boiler be suspended from the cellar joists and connected with a coil in a furnace. The regulations here require that a check valve shall be placed between the meter and the boiler, which I consider a dangerous practice, and as yet have never done it, as there would be no chance for expansion. Am I right? The meters here are easily spoiled by hot water, as the pistons are made of hard rubber."

Yes, he is right. The writer has found that they have a law compelling the use of a check valve, to be placed between the meter and the boiler. It seems most absurd that the superintendents of water works should insist on such installation without also requiring that relief valves be placed in the same line of pipe between the boiler and check. It has

been suggested that a small hole could be drilled through the clapper of the check valve, but this in time would become clogged. This would render such an arrangement useless.

Catalysis in iron pipe has without doubt been the cause of many bursting boilers. It is a fact that, even up to the point of complete stoppage, some water will find its way through a corroded or stopped pipe, but inversely, when expanding water seeks egress back through a pipe clogged with corrosion or catalysis, it acts very similar to a swing check valve and prevents its free passage.

I wish to make a brief résumé of some of the tests which I have made in the last few years on various so-called "water relief valves." I have picked out these few at random from a great many that I tested.

There is nothing new in the idea of using water relief valves on pressure boilers. As early as 1880, 43 years ago, the Carr Valve and other valves similar in design, with lever and weight attachments, were on the market. This design of valve has been condemned for use on both low and high-pressure steam boilers in this state. Any one may tamper with the weight and unknowingly increase the load by the slightest movement of same from 15 to 25 lb. On one occasion a plumber was called to a house to replace a boiler that he had installed a short time before. The boiler was leaking and the valve had previously leaked, and to stop it, the lady of the house had hung a flatiron in addition to the weight upon the lever.

On an American Steam Gauge Relief Valve the lever acts diametrically opposite to the one previously described. In action, the end opposite the fulcrum is lowered instead of being raised. It would be an easy matter, in case of leakage, to stop further action of the valve by propping it tight with a stick, one end resting on the floor and the other under the lever.

A view of the Ashton Relief Valve in section would lead you to believe that its construction is mechanically correct. My comment would be that there are too many metal and mechanical parts to it. One of these valves was set at 100 lb., and after 2 years' service it was tested and found to blow at 240 lb.

The Ryan Relief Valve is a combination vacuum and relief valve, probably the first valve that was ever made for use on this type of work having a soft metal or lead disc. As made, this feature would have been of no consequence, as lead fuses at approximately 620 degrees, F. After one of these valves was in use a short time it was removed and tested. It blew at 380 lb.

In a Mueller Relief Valve (small screw, $\frac{3}{8}$ in.), the restricted waterway makes the valve of little consequence. In fact, many of the towns and cities will not permit the use of a relief valve in which the waterway is less than $\frac{1}{2}$ in. The V-shaped arrangement of disc and seat should condemn it. One of these valves was set at 90 lb. It was in use less than two years. It was tested when taken off and found to blow at 280 lb.

I am glad that the Mueller Company redeemed themselves by placing their Diaphragm Relief Valve upon the market. Conversely, the operation would be almost identical with the pressure reducing valve, and you can readily see how great a motive power could be generated under the diaphragm of the valve in case of an emergency to assist in raising the disc from its seat. Comparing the diameter of the disc and diaphragm the relative value is about one to twenty-five. I wish that I had time to tell you a story about a plumber who placed one of these valves directly in the supply to the range boiler, so that the water had to pass through it in order to reach the boiler.

As stated before, the Boston Self-Closing Bibb would afford an automatic relief for excess pressure in the hot-water system, it being required that only enough pressure be generated on the under side of the disc to overcome the tension of the spring, causing the disc to rise from its seat. The chief objection to the use of a self-closing faucet is the sudden shock or strain thrown upon the system of piping when the handle of the faucet is released.

The repeated shocks or recoils from water hammer when self-closing faucets are used are deleterious to the system of piping, and when copper range boilers are used, have a tendency to weaken the material and mechanical construction of the boiler.

Undoubtedly with a knowledge of these facts in mind, Stack designed his Combination Faucet and Relief Valve, eliminating the objectionable features already described. When in ordinary use, it is operated the same as the lever-handle compression bibb.

When acting as a relief valve for excessive hot water, the excess accumulated pressure overcomes the tension of the spring and causes the disc, which is movable, to rise from its seat, allowing the accumulated water to escape and relieve the pressure. When used as an ordinary faucet, the frequent use of same is an assurance that the disc will not stick or adhere to the seat as it is moved with each operation of the faucet.

In Fig. 4 you have an optical demonstration of the breaking of a copper boiler while under pressure. The boiler was equipped with a water relief valve set at 100 lb. The boiler had the manufacturer's stamp on the side stating that it had been tested at 200 lb. The boiler burst at 140 lb. cold-water pressure.

There is nothing new about the so-called pressure or closed system of domestic hot-water supply. When it originated undoubtedly the pressure in the water mains and supply pipes was much less than that required to-day, and galvanized-iron boilers were used on pressure systems almost entirely. It was not unusual in cities where the pressure was low, to draw hot water from the hydrants in the street, at least I have been told so by men older than myself, who should know. This would indicate that the natural relief for expanding hot water is back into the main, and personally, after 35 years' experience in the plumbing business, I cannot

understand in these enlightened times, why any one should desire to prevent it.

In raising the temperature of the water in a 30-gal. boiler from 60 to 212 degrees at atmospheric pressure, there would be discharged from the boiler theoretically every minute, assuming 1 hr. is required for this change of temperature, a slug of water of approximately 5 in. This, multiplied by 60 minutes, would equal 300 in., or 25 linear ft. of water in a 1-in. pipe. Under ordinary conditions, with the heating surface of the water front properly proportioned in relation to the boiler it served, the expanding water would cause no injury to the meter. The troubles that we have

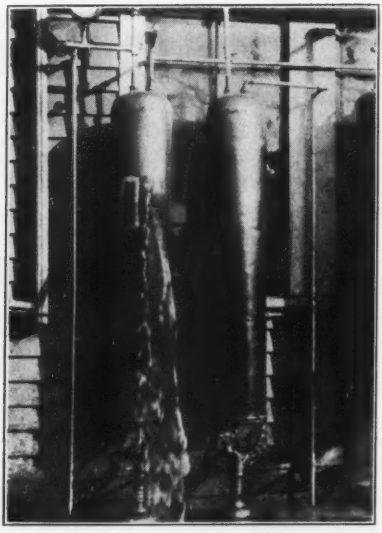

FIG. 4.

had, and are still experiencing, are due, as previously stated, to excessive heating of the boiler, and consequently a larger volume of expanding water from the boiler. This trouble could be regulated by efficient inspection.

I have heard it said that a water meter was so constructed that it acted as a check valve and prevented back pressure. If I am correctly informed I do not believe that this is so. Although the mechanical parts of a meter might become disarranged or enlarged on account of expanding hot water, I do not believe it possible for this condition to become so acute that the inlet and outlet ports of the meter would be entirely blocked. Would the cost of constructing meters that would withstand hot water be prohibitive? I have been told that a certain city had water meters constructed so that the meter, itself, constituted a check valve, and as a

result of the damage caused to properties in which the meters were installed, it is the defendant in several suits.

If a check valve is introduced into the main supply pipe of the house for the protection of the water meter, what assurance will be given the house owner that his home, as well as the lives of his family and himself, will not be placed in jeopardy? Can it be possible that a man representing a city would do what I heard one superintendent say when I spoke before your Association previously, that he would insert the check valve and the owner must look out for himself?

I have been told that many of the superintendents of water works still persist in their idea that a check valve should be placed in the line of supply to the boiler in order to prevent hot water from the boiler expanding back through the meter. The illustration following represents a fact and not a theory. I, personally, made the installation shown in Fig. 5, with

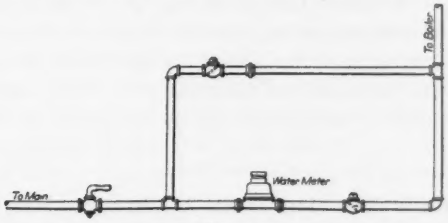

FIG. 5.

the permission and under the direction of a superintendent of water works who is a member of your Association. Briefly, when the boiler was fired in its usual manner, and the main shut-off closed, and the top of the upper check valve removed, hot water from the boiler expanded back and over the top of the check valve at regular intervals.

With the top of the check valve in place, and the shut-off open, the click of the check valve could be heard at regular intervals as the expanding water from the boiler passed through it. The clapper of this check valve was arranged to swing outward or towards the pressure. The clapper of the lower check valve was arranged to swing inward towards the boiler. At no time during the test did hot water pass the lower check valve. Both check valves were of the swing check pattern.

At the time I made the test just referred to I did not know of the patented device called " the Protector." I have no idea what the cost of this device would be to-day, but if it will protect the meter (and that seems to be the chief desire of many of the superintendents), and allow the expanding water egress into the mains, it is an assurance against boiler explosion, and a cheap investment at any price.

Few of us realize the small amount of water required to generate a tremendous volume of steam. In comparison, it is said that 1 cu. in. of water, when evaporated into steam, is equivalent to 1 cu. ft., or 1 728 cu. in.

At a temperature of 215 degrees a pound of steam is equal in volume to approximately 27 cu. ft. At 100 lb. pressure the temperature is equivalent to 337.5 degrees, and 1 lb. of steam occupies approximately 2 cu. ft.

This will give you some idea of the terrific force expended when the steam is allowed to escape through a rupture in a boiler. I doubt if many of you comprehend the tremendous pressure to which the average range boiler is subjected. At 100 lb. pressure, the total surface pressure which it is required to withstand, is equal to 195 400 lb., and this does not include the top and bottom heads of the boiler.

Time does not permit of my dwelling on the spheroidal state, but I am strongly of the belief that this phenomena obtains under certain conditions, and especially in the copper coil of a gas heater, and the water front or brass coil of a range, when they are under pressure and overfired, with an inadequate supply of water.

A majority of the range boilers are constructed of too light material. Even the apparently strong galvanized-iron boiler is not immune from this defect. Table 2 shows some tests on three galvanized-iron range boilers and at what pressure a permanent set was placed in the head of one of the boilers. Occasionally a galvanized boiler, strong as it appears to be, explodes.

TABLE II.

RESULTS OF TESTS MADE BY WM. A. BRADFORD, QUINCY, ON 30 GALLON 12′ x 5′ MASSACHUSETTS REGULATION RANGE BOILER.

TESTS MADE ON MARCH 22, 1917, AT RIVERSIDE BOILER WORKS, INC.

Manufacturer	Weight	Height Over-all	Height On Shell	Inside Diam.	Outside Diam.	Gage Shell	Tested to	Remarks
John Woods Mfg.	52 lbs.	62⅛″	60″	12″	12 1/16″	12	230 lbs.	*
W. B. Scaife Co.	95 lbs.	61¾″	60″	12″	16 1/16″	12	200 lbs.	†
Riverside	101 lbs.	62½″	60½″	12⅛″	12⅜″	11	230 lbs.	*

DISH OF BOTTOMS

Wood 3⅛″ Riverside 3″ Scaife — Bottom concave and convex shape. 1½″ in at rim, ½″ out at center.

TEST ON RIVERSIDE DOUBLE EX. HVY. KOPSTEEL BOILER.

This boiler is a 300-pound test, 127½ pounds working pressure Massachusetts Regulation boiler, shell 10 gage, bottom 2/16 inch, made of copper steel, and carries a time guarantee of six years.

Weight 120½ pounds. Dish of bottom 2¾ inches. Tested to 300 pounds plus. At 300 pounds there was not a hair bulge to bottom.

* Bottom did not bulge a hair.
† At 120 pounds moved out slowly 1/16 inch. Between 160-180 came out ¼. At 200 pounds total bulge 1/16. Bottom was permanently set.

In Massachusetts the district police have jurisdiction over construction and inspection of both low and high-pressure steam boilers when used in public buildings, halls, factories, mercantile buildings, and so forth. The safety valve on low-pressure boilers is set to blow at 15 lb. pressure. On high-pressure boilers the valve is set in proportion to the strength of the boiler.

In both cases the valve has a lock-up attachment so that it cannot be molested. Each boiler is provided with a fusible plug, gage, and water cocks. Before the boilers can be operated it is necessary to obtain a permit from the district police after the boilers have been inspected and found to comply with the necessary laws and regulations. This permit must be renewed, after certain requirements have been complied with, each year. Certain rules are laid down by the Board of Boiler Rules governing the tensile strength, thickness of plates, joints, type of rivets, and general construction of the boiler.

I have cited all these conditions because in the manufacture of copper and galvanized-iron pressure range boilers no such laws prevail, and yet the element of danger in the use of the average kitchen pressure range boiler, with its varied heating attachments, is ten times greater than that of the safeguarded wrought and cast-iron steam boilers.

The city of Boston has recently put into force an ordinance making it compulsory to install pressure, temperature, and vacuum relief valves on all new boiler installations in the future. I find no provision in this ordinance for safeguarding the installations which are already in use. In my estimation, this ordinance or law is of no particular value. I find no provisions incorporated in the law for its enforcement.

I will now describe some of the relief and temperature valves of more recent design and manufacture. The Donnelly Water Relief Valve may be adjusted by the plumber and then locked up. This is not a good practice. The valve should be set at a certain pressure by the manufacturer before it is installed, and so locked or sealed that it could not be molested afterwards. I have been told that the Boston Ordinance was based on the principles involved in this valve.

The Red Top Relief Valve is one of the later models and seems to be an innovation for this type of work. The Boston Ordinance as drawn says, " The valves can have no interior weights, and must be of such type that the plumber must adjust them to the pressure required on the job." I fail to see how this valve can qualify, although the same company makes a valve of larger design with movable or adjustable weights in which the power of resistance may be increased or decreased. My personal objection to this valve would be the possibility of the spindle or stem sticking in the guides and at the seat. A type of valve similar to this has become obsolete, at least in this state, on steam-boiler installations.

Donnelly's Temperature Valve is distinctly a temperature valve, and pressure has no bearing upon it whatever, except as it affects temperatures. Its action would be identical with an ordinary fusible plug, except that the

composition of the metal should be such that it would fuse at a lower temperature — for safe practice, not exceeding 225 degrees.

The Smith Temperature and Water Relief Valve, in my estimation, is a distinct innovation, and a step in the right direction. The lower fusible plug which is the first to fuse and relieve excessive temperature, melts at approximately from 215 to 220 degrees. Instances have come to light where the plumber boastfully stated that after the valve blew, to save the householders further annoyance, instead of inserting a new fusible plug, leaving the valve in order for the next emergency, he wilfully plugged it with a wooden plug; but the inventor has tried to make the valve foolproof, and about halfway up on the tube of the valve there is another fusible plug which the plumber cannot molest as easily, and which melts at approximately 240 degrees. The pressure relief feature is near the top of the valve and is contained in the upper chamber. The tension of the spring holds a fiber disc washer on the seat of the valve except when overcome by excess internal pressure.

Quite recently I spent two days with the inventor of the Smith Valve, testing this valve. In every instance the valve did exactly what was claimed for it. The results of the most interesting test, no relief valve attached, open system, are as follows:

Time, 3.30, temperature 60 degrees, pressure 45 lb.

Time, 3.42, temperature 285 degrees, pressure jumped from 45 to 50 lb., instantly. Hot water was forced back through the feed pipe seeking relief, and pressure dropped to 45 lb.

Opened Bibb, first, a flush of hot water from 6 ft. of $\frac{3}{4}$-in. pipe to empty it. Then it blew steam from 15 to 20 sec.

I also make these deductions after witnessing the tests:

First. That water heated to above 180 degrees is a waste of gas.

Second. That flow pipes from heaters should not be less than $\frac{3}{4}$ in. in diameter to prevent waste of gas, as the velocity of the water through pipes of smaller diameter is not fast enough.

Third. That boilers of greater capacity and heating agents of less energy should be used; that is, they should be more carefully proportioned, one to another.

Fourth. Drip or waste pipes from relief or temperature valves should be vented by an open tee end or sniff hole close to the valve connection to prevent siphonage of water from boiler when valve is open.

Gentlemen, in conclusion, let me say that the element of force evident in all boiler explosions, and the possibilities contained in any boiler heated under pressure, are greater than those of gunpowder, nitroglycerin, or TNT. Limited time permits of only briefly qualifying this statement. Water heated under 20 lb. pressure in a 30-gal. boiler, if given an opportunity to expand or flash into steam, will equal 4.75 per cent of the contents, equal to 11.1 lb. of water, equal to a volume of steam of 298 cu. ft., equal to 914 000 ft. lb. of energy let loose.

One pound of black powder, if exploded, would develop 960 000 ft. lb.

of energy. Change the pressure of the water in the boiler to 70 lb. pressure, and increase the other factors in their respective ratio, and a ruptured boiler would then liberate 2 642 000 ft. lb. of energy.

One pound of nitroglycerin, if exploded, would liberate 2 000 000 ft. lb. of energy.

Why do boilers explode?

First. Excess pressure from expanding water causes a rupture in the boiler at its weakest point.

Second. The sudden release of the energy confined in the boiler as it expands blows the building asunder, enough power remaining in the boiler to blow it from its former location as though it were a projectile being discharged from a gun.

Did you ever notice the absence of water in a room where a boiler explosion had occurred?

I will end this talk with these conclusions and suggestions:

First. That laws should be enacted placing the installation of this type of work under the direction of the District Police, Department of Public Safety.

Second. Installation of work should be made only after a permit has been issued, and at its completion the work should be inspected.

Third. Each pressure and cistern boiler should be equipped with a vacuum valve.

Fourth. Each pressure hot-water boiler or tank should be equipped with a water relief and temperature valve, with lock-up attachment, but so arranged that they can be operated without changing the adjustment.

Fifth. No obstruction should be placed in the feed pipe to boilers to prevent expansion of water from the boiler or in the circulation pipes of the boiler.

Sixth. The amount of heating surface should be regulated in proportion to the capacity of the boiler.

Seventh. A thermostat automatically controlling the supply of gas should be used with all gas water heaters when attached to hot-water boilers.

Eighth. The size of tank heaters, when used in conjunction with hot-water boilers, should be regulated and equipped with automatic devices controlling the draft of the heater.

Ninth. The manufacture of pressure range and other hot-water boilers and tanks should be under the supervision of the Department of Public Safety.

Tenth. Any other reasonable laws and regulations safeguarding existing and future installations of boilers on this class of work should be enacted.

If a course were pursued similar to that which I have described, with the assistance of your Association, the district police, the Master Plumbers' Association, the Heating and Power Engineers' Association, and the coöperation of the gas companies and boiler manufacturers, I am sure that we could obtain results, and at least try to prevent by supervision the frequent explosions of range and other hot-water boilers.

TOPICAL DISCUSSION.

Standardization of Water Meter Registers.

[*September 20, 1923.*]

President Sanders. Mr. Hawley, will you start the discussion on water meter registers?

Mr. W. C. Hawley.* I came here to get some information on this subject. I do not know that I can give very much.

A year ago last summer while my family was away I went home one evening and discovered a postal card under the kitchen door, left there by the Natural Gas Company, with the statement that the inspector could not get into my house to read the meter and requesting that I indicate on the dials printed on the postal card the positions of the hands, and mail it to the office. It struck me as a pretty good scheme. I made some inquiries of the gas company and found they were getting about 75 per cent of their "pick-ups" by this method, instead of having to send a man back in all cases to get the reading.

I thought that would be a good thing for water meters, and I started to get some cards ready. I did not realize until then what a difference there is in the registers of the various makes of water meters, and not only in the various makes, but in some cases in the registers of different meters made by the same company. I finally did get up cards. I gave up trying to reproduce the registers. I identified the different dials by the 10, 100, 1 000, 10 000 figures, and so on, and we have been using cards of that kind very satisfactorily. I was able to get them down to three; one card for the "straight reading" registers, then another card to fit the "Hersey-Nash-Keystone-Pittsburg Disc and Arctic" meters, and another card for the "Gamon, Worthington and Trident."

But that called to my attention the difficulty which our meter readers encounter as they go about reading meters, — the difference in direction of the rotation of the hands, the difference in the arrangement of the dials, etc., — and it seemed to me that if there could be a standardization of the meter registers it would eliminate a great deal of trouble and perhaps many mistakes. Of course it could not be done in a month or a year; it would take a long time, but we have standardized the threads on fire hydrants, though it is going to take a long time to get the standard generally adopted, and it seems to me that this is a thing that is worth trying.

I have discussed the matter with various other gentlemen, and those with whom I have talked seem to think that it is worth while to take this matter up and see if the registers cannot be standardized.

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* Chief Engineer, Pennsylvania Water Company, Wilkinsburg, Penn.

MR. J. M. DIVEN.* You took this matter up with the Joint Committee on Standard Specifications for Water Meters. How did you come out with them?

MR. HAWLEY. I did, but unfortunately the matter was not brought to their attention until I guess the report was pretty nearly agreed upon. At any rate, they decided it was not advisable to take it up at that time, I believe.

MR. CALEB M. SAVILLE.† I would like to say that while the final report of the Joint Committee was submitted to the American Water Works Association at its convention in May, and the report was accepted by the Association, the committee of the American Water Works Association on this matter was continued for the purpose of considering just this matter, and I don't know what action the New England Association has taken in this connection. Perhaps the Association here would like to take some action on it, because it seems to me it is a very important matter. The meter manufacturers, as I understand, are very willing to coöperate in any reasonable way, and I believe something of this kind could be worked out in time just the same as the standard specifications have been worked out.

MR. DAVID A. HEFFERNAN.‡ I would like to ask Mr. Hawley if he made inquiries in regard to the practice of sending out these cards. If he did not, I would suggest that he write to Mr. Kingman at Brockton. They have been using them for some time.

MR. HAWLEY. We have been using these cards now for some time ourselves, and we get about 50 per cent of our readings with the cards.

MR. JOSEPH A. HOY.§ The same practice has been going on for a number of years in Worcester. Mr. Batchelder at the present time has put out cards indicating the round registers or the oblong registers, for the parties to indicate on the cards their meter readings. It has been a practice in Worcester for a number of years to use some kind of cards.

PRESIDENT SANDERS. How does he allow for the different makes of meters?

MR. HOY. He has one card for the oblong readings and one for the round readings.

PRESIDENT SANDERS. Are there any members here from the Manufacturers' Association that would care to say anything on this subject?

MR. CHARLES W. SHERMAN.‖ If Mr. Blanchard were here he would be best fitted to speak for the manufacturers' committee.

PRESIDENT SANDERS. I think we would be glad to hear from Mr. Blanchard.

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* Secretary, American Water Works Association.

† Chief Engineer, Board of Water Commissioners, Hartford, Conn.

‡ Superintendent, Water Works, Milton, Mass.

§ Foreman, Water Works, Worcester, Mass.

‖ Of Metcalf & Eddy, Boston, Mass.

MR. W. K. BLANCHARD.* The standard specifications for cold-water meters — disc, crest and compound type — have just been completed, and it is a question whether or not it would be advisable at this time to carry on any further standardization work.

The question of standardizing water meter registers has been taken up not only in the discussions held among the manufacturers, but also in the joint committee meetings of the New England and American Water Works Associations. The situation regarding water meter registers is this:

There are eleven different types of registers, round reading, having location of digit wheels in different places. In some of the cases the hands on the digit wheels *all* turn clockwise; while, in most of the registers, the hands of the round reading registers alternate in turning clockwise and anti-clockwise for the different digits.

Another point is that in some of the registers the unit digit or test dial is located on the top of the register, while, in other registers, the unit digit is located at the bottom of the register.

In some cases the increase from units to the higher digits occurs in an anti-clockwise direction, while in other cases, the unit digits to the higher digits occur in the clockwise direction. Thus it is seen that there are a multiplicity of combinations now being made and in use on round reading type of registers.

Whatever standardization on registers that might occur should be done by the joint committee of the two Associations, as, if the manufacturers endeavor to use a standard construction, a considerable amount of complaint would be received on account of the change from the register which has been supplied and used for many years.

Speaking for the Manufacturers' Standardization Committee, would say that the problem has already been gone into and has been found a difficult one for solution. The manufacturers, however, would be very glad to coöperate at any time with the Associations and extend hearty coöperation to them.

In the case of the larger meters, say, over 1 in., there is a still more difficult problem. However, in case of the large size meters, it is assumed that you would want your meter man to read these meters anyway. Therefore, it is the registers of the domestic meters that you would be most concerned in standardizing.

In most manufacturing plants, where large meters are installed, they are almost always accessible, and the meters can be read and should be read by the meter reader because it is a good thing to look over a meter at least as often as a man reads it, whether it be every month or every three months.

Speaking for the manufacturers, I can assure you that whatever the New England and American Associations want done, they will have the hearty coöperation and support of the Meter Manufacturers.

* Assistant Secretary and Engineer, Neptune Meter Company.

MR. SHERMAN. I hardly know what to suggest in view of my not being absolutely certain as to what the action of the Association was, but perhaps it would do no harm to pass a vote that will enable us to straighten out the matter if my recollection is right, and it will do no harm if it is not.

I therefore move that the Executive Committee be authorized to reappoint or revive the Association's committee to work with the corresponding committee of the American Water Works Association on Meter Standardization, if in its judgment it seems wise to do it.

(The motion was duly seconded and carried.)

TOPICAL DISCUSSION.

USE OF BRASS PIPE FOR SERVICES.

[September 20, 1923.]

PRESIDENT SANDERS. The next subject is the "Use of Brass Pipe for Services." In these times when we are getting so much trouble with red water, and using cement-lined, wrought-iron and steel pipe, I think that a discussion of this subject is a very proper one, especially at the Superintendents' session.

MR. DAVID A. HEFFERNAN.* There are so many good pipes and materials used for services to-day, I am going to put it this way. I think the brass pipe in cost is prohibitive.

MR. J. M. DIVEN.† I have been giving considerable attention to this matter. The cost of brass pipe, heavy brass pipe, is about the same as 2-A lead pipe. Pure copper pipe, which probably has some advantages over brass, is about the same as 3-A lead pipe. Now, that hardly seems prohibitive, because I think lead pipe of those weights is being used quite generally. I think in a majority of places — I don't know about New England, but through the Middle States and Western States and the Middle West, lead pipe is being used more extensively than anything else. Now, as to any cheap material, if the cheap material is not long-lived, I believe the cost of digging up the paved street and renewing the service would be prohibitive.

MR. R. W. WIGMORE.‡ A few years ago we put in a few services of galvanized pipe and their life was not over seven years. We have lead pipe which has been in use between sixty-five and seventy years, and in many cases it is just as good to-day as it was the day it was laid.

MR. CALEB M. SAVILLE.§ When the gentleman says seven-year-old galvanized pipe, he probably means galvanized-steel pipe and not galvanized wrought-iron pipe.

MR. WIGMORE. Yes, that is steel.

MR. SAVILLE. It has been the experience that galvanized-steel pipe will last in the neighborhood of six or seven years, but you do not get into trouble with galvanized wrought-iron pipe for fifteen to eighteen years. We have some old wrought-iron pipe in service that has been in service forty years.

MR. WIGMORE. This is steel I spoke of.

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* Superintendent, Water Works, Milton, Mass.
† Secretary, American Water Works Association.
‡ Commissioner of Water and Sewage, St. John, N. B.
§ Chief Engineer, Board of Water Commissioners, Hartford, Conn.

MR. DIVEN. There is another consideration with the cement-lined pipe, and that is soil corrosion. You are back to iron pipe as far as the action on the outside of the pipe goes.

MR. HEFFERNAN. I would like to have the members go to the Union Meter Company's table at the exhibit hall, and you will find a section of pipe taken out in the city of Worcester. It is cement-lined pipe that was laid in 1865, and the pipe is in good condition. The interior is perfectly lined, and hardly any corrosion on the outside.

MR. JOSEPH A. HOY.* The piece of pipe that the Union Water Meter Company has on exhibit was taken out of a service in the city of Worcester about two years ago. It was installed in 1865 and was one of the first services. There is very little outside corrosion on it, and the cement probably looks as good as the day it was put in.

At the present time we are using small steel pipe, 1-in. lined to $\frac{3}{4}$ in., costing about 12 cents per ft.; and $1\frac{1}{4}$-in. lined to 1 in., costing about 15 cents per ft.

MR. SYDNEY L. RUGGLES.† I want to raise the same question Mr. Diven has already done. My experience in replacing old services has been that we get more corrosion on the outside of the pipe than on the inside, and most of the leaks that we have had to repair in the old services have been due to the fact that the outside had rusted away. There may be a difference in water, although most of our services have been in about thirty-five years. They are evidently wrought iron, because you can see the characteristic of the structure. But they would go a good many more years with no trouble from the inside. I do not know how lining them with cement would affect them.

MR. DIVEN. They could be protected on the outside with cement.

PRESIDENT SANDERS. The custom in my city, with a private owner — our water is very soft and will fill up a galvanized pipe, wrought-iron or steel, in a period of about eight to thirteen years — is that almost every one in the city now, when they replace their services, use brass pipe. We lay the service from the main to the street line, and they are practically all using brass pipe from the street line to the inside of the cellar wall.

MR. BRISTOL. What size?

PRESIDENT SANDERS. Three-quarters of an inch. We take an inch pipe and reduce it to $\frac{3}{4}$ in., and then they will lay a $\frac{3}{4}$-in. brass pipe to the inside of the cellar wall.

MR. BRISTOL. Is that large enough for these automatic valves that they are now using without tanks on toilets?

PRESIDENT SANDERS. No, I hardly think so.

MR. F. N. SPELLER.‡ It may be unwise to get started on this subject, because it is one that ought to take a whole evening, but we have heard a

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* Foreman, Water Works, Worcester, Mass.

† Superintendent, Water Department, Barre, Vermont.

‡ Metallurgical Engineer, National Tube Company.

great deal lately in popular advertising about the virtues of brass pipe, and of course we recognize its advantages. But we hear nothing at all about the weak points of brass, and I think an engineer naturally wants to hear both sides of such a question.

Of course I am speaking in a very general way on this subject. We all know that all kinds of metal are subject to corrosion. All common metals are subject to corrosion in various kinds of water. Lead, for instance, has been used since the time of the Roman Empire, and yet to-day it is legislated against in some places on account of the effect of certain kinds of water. They would not think of using it with some water, but it gives good service with others. And that is also true of copper. It is inadvisable to use copper in salt water — hot salt water especially.

Brass pipe has been used for some time, although not nearly as widely as you might think. The annual production according to the most reliable data available does not exceed 20 000 tons. The tonnage of steel pipe amounts to 2 500 000 tons. So that while brass is a factor, it is an expensive pipe with limited uses.

Now, brass pipe, like all the other metals, will last well in some waters, and in other waters there is a peculiar kind of disintegration that none of the other metals are subject to, for the reason that brass is an alloy, whereas copper, lead, iron, and steel are elementary metals. This peculiar disintegration which occurs in certain places is probably due to the fact that the alloy is not uniform, so that you get an electrolytic effect which results in the solution of the zinc, leaving a residue of copper, the result being a heavy loss in ductility and strength of the metal. This occurs particularly at the couplings, because the coupling materials are cast brass, which is a different composition from the drawn pipe. The result is disintegration and weakness at the root of the thread and a liability to break off at this weak point. There have been to my knowledge twenty or thirty instances of this in my native city of Pittsburgh, and I know that it has occurred to a serious extent in other cities, both in hot and cold-water lines. Now, that is not condemning brass pipe for all purposes, because there are other localities where this does not occur, and where one may safely use brass pipe if you want to pay the price. So also there are many localities where galvanized-iron and steel pipes do not corrode seriously. But, on the other hand, steel, as we all admit, has a high degree of ductility and strength. It is the strongest pipe of all, and for service lines the inside can be protected from corrosion by a cement or lead lining. The cement lining was developed in New England where it has been used for 50 or 60 years. Means are now available for removing the oxygen economically from water which will stop corrosion of any metal.

The outside of the pipe can be protected by a number of means, where protection is required. The bituminous coatings, and especially those that are reinforced by saturated fabric, are not used nearly to the extent they might be used. The gas companies have gone into this subject in

detail and have developed suitable protective coatings for use when such are needed.

In closing I just want to add this in taking issue with Mr. Saville in regard to the iron versus steel question. As he knows, I do not agree with him at all in his statement; no definite evidence on the superiority of wrought iron has been submitted. The fact that one line lasts 30 or 40 years and another line lasts perhaps half that time does not prove anything at all. Conditions have everything to do with corrosion. There is this to be said, however; that engineers have recognized the fact that corrosion is largely a question of external environment, and in order to get a comparison you must have the two materials together in service under the same environment. On that basis, during the last 20 years there are on record many tests made by independent engineers in water lines, where pipes were put together carrying the same water, and where the tests were run to destruction. The results show no difference between iron and steel on the average; sometimes a little difference one way and sometimes the other. But on the general average there is no difference at all.

Sometimes we hear of a case where a service line has been in use for a number of years, when the line is taken up and a piece of modern pipe — no matter whether it is iron or steel — is put in. Perhaps this pipe gives trouble in half the time, and this circumstantial evidence is used against the more modern pipe. But in the meantime many factors may have changed. For example filtration plants may have been introduced, and it has been found that the protective coatings, formed by deposits of inorganic and organic materials on the surface of the metal have a great deal to do with retarding corrosion. Now, if these natural protective factors are lacking and you put new pipe in with clear filtered water that has lost its power of protecting the metal, what is going to happen?

MR. HEFFERNAN. There is one element which I think has not been considered, and that is the electrolytic action or galvanic action. I would like to ask the former speaker that, if in his judgment, if the brass pipe tubing is a somewhat different alloy than the fitting, would there be more chance for corrosion than there would be with the wrought-iron or steel pipe and fittings. The reason I speak of this is because I have had considerable experience in connection with electrolytic action; that is, from the grounding of wires on the pipes. We have found from experiments that the telephone and the electric grounding on the water pipes has caused galvanic action. This has had a very bad effect indeed on the pipes. Now, this is a subject for discussion that is going to be continued at some time in this Association. As I understand it, Mr. Diven, the American Association went on record as allowing the grounding of telephone and electric wires on their pipes.

MR. DIVEN. Alternating current. That was following the action of the National Board of Fire Underwriters.

MR. HEFFERNAN. Probably most of you gentlemen have read in the

papers of a case in the city of Newton where copper pipe was substituted for brass pipe in the bathroom, and when the water was used the sponges turned green. It was looked into and experiments were made, and the result was that the trouble was traced to the grounding of the wires on the pipe. An insulating joint was inserted on the house side and a further test was made, and the green substance on the sponges disappeared.

Now, this is an important subject, and a joint committee is appointed from the American and New England Associations to make a further study. I am a member of that committee, and I hope in the near future that we can get together and get some information on the subject.

PROCEEDINGS.

November Meeting.

City Club, Boston,

Tuesday, November 13, 1923.

The President, David A. Heffernan, in the chair.

Mr. Caleb M. Saville. Mr. President, I would like to make a motion that this Association put on record an expression of its sympathy with Mr. Charles W. Sherman in his illness, and also as a practical mark of its appreciation of his services to the New England Water Works Association that the President and Executive Board be authorized to send flowers to Mr. Sherman with the compliments of the Association, and as a reminder of the loss the Association feels in his absence from this meeting.

(The motion was duly seconded and unanimously carried.)

A paper on " Cause and Effect of Range-Boiler Explosions," illustrated with the stereopticon, was delivered by Mr. William A. Bradford, Quincy, Mass.

Mr. W. K. Flavin of Boston read a paper, illustrated with the stereopticon, on " Problems the Flush-Valve has Solved and Others it has Created."

Adjourned.

FRANK WELLINGTON HODGDON.

Frank Wellington Hodgdon died at Arlington on January 26, 1923. He was born in Arlington on January 12, 1856, attended its schools, and graduated from the Massachusetts Institute of Technology in 1876. His entire professional life was devoted to the service of the Commonwealth, which he entered soon after graduation as engineer of the Harbor Commissioners in 1876. Throughout all the subsequent changes in the organization of the state department having to do with the harbors and public lands of the Commonwealth he continued in the same line of service for a period of forty-seven years. The list of the improvements in the lands and public works of the Commonwealth carried out in accordance with his designs and under his direction is a long one and includes the extensive improvements made in Boston Harbor and the estuaries about it within the last half century, and especially in recent years. The great Commonwealth dry dock, the largest in the United States and second largest in the world, was built after his designs and under his direction.

In addition to his work upon the harbors of the Commonwealth he was active in the reclamation of lands from the inroads of the sea and was early connected with the measures for the improvement of the Province lands where an effective work has been done in preventing the shifting of the sands in the region north of Provincetown. The work of inducing a growth of vegetation capable of thriving upon these areas has resulted in gradually reducing them to stability and has removed conditions which had become a serious problem. He was appointed in 1897 a member of the commission on a topographic survey map of Massachusetts charged with making a survey of the municipal boundaries, and later on when this commission was merged with the Harbor and Land Commission he completed the town boundary work in 1915. This work is of great and permanent value and will furnish the foundation for an accurate map of the state and its cities and towns, a great need in a state so densely populated as Massachusetts. In connection with the town boundary surveys he had charge of the surveys and re-marking of the state boundaries bordering Rhode Island, Connecticut, and New York, and was a special commissioner upon establishing and marking the boundaries between Massachusetts and the states of Vermont and New Hampshire.

In connection with the work of his department he prepared the reports and estimates for the proposed canal from Taunton to Boston and was also consulting engineer on the Cape Cod Canal. His engineering activities were not confined to the limits of Massachusetts. On account of his ex-

tended experience in such matters, he was appointed in 1911 by President Arosemena to represent Panama on the commission of engineers on the Costa Rica-Panama arbitration. He was also in charge of the improvements of the Florida coast-line canal from St. Augustine to Key West and was consulting engineer in connection with other similar developments.

He always took an active part in the work of the various engineering societies and was interested also in the International Association of Navigation Congresses, of which he was a member.

In his home town of Arlington he played a leading part in public affairs, giving his time freely to a great variety of committees having to do with public improvements and public interests in general.

His thorough knowledge of everything pertaining to harbors and waterways and their development and protection, united with a firm courage, sound judgment, and a most agreeable personality, made him invaluable as an adviser in all matters relating to such subjects, and because of these qualities his advice was in constant demand by legislators and others having to do with such questions. Faithfulness to the service of the state and unswerving loyalty to its interests and to the highest ideals of his profession leave a record of public service rarely equalled in his time.

X. H. GOODNOUGH.
F. A. MCINNES.
Committee.

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of Membership in the N. E. W. W. Association ($1.50), and Membership Button ($1.00), which please mail me and oblige

Yours truly,

HERSEY DISC METER, MODEL HF, which is the highest type of Frost protected Meter and HERSEY DISC METER, MODEL HD, which is the highest type of divided or split-case Meter, are the product of thirty-five years' experience and refinement in the manufacture of Water Meters. These Models excel all Meters of all makes in all those essentials which go toward making exceptionally desirable Meters.

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FROZEN!—but not damaged

Here is an actual photograph of a LAMBERT Frost-proof Meter which has been frozen to an extent that would put the ordinary meter completely out of commission.

This is made possible by a patented, non-corrosive yielding bolt device which allows the upper and lower casing, disc chamber and gear train to part without damaging the meter in any way. Five minutes' labor the only repair cost.

The expense and annoyance from frozen water meters can be eliminated for all time through the installation of the LAMBERT Frost-proof.

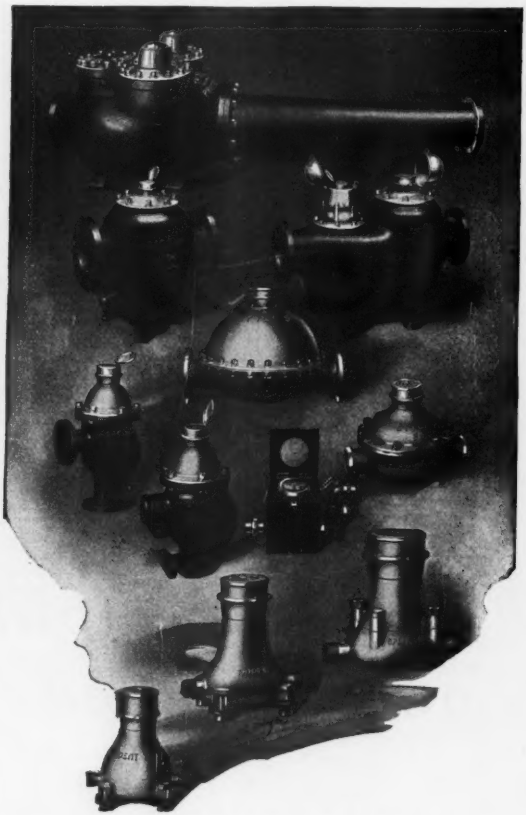
It has been proved that the LAMBERT is the easiest water meter to take apart and put together again as well as the simplest, most reliable and accurate.

If you are interested in other types of meters, we make one for every requirement.

THOMSON METER COMPANY

100-110 BRIDGE STREET BROOKLYN, N. Y.

LAMBERT FROST-PROOF METERS



A Trident for Every Service!

WHY are there more than two million TRIDENTS in service?

There is only one reason,—TRIDENTS are more continuously accurate, more durable, more economically maintained. They are the *best* meters. Don't stint quality — you need the best for *your* services!

Have you seen our latest development,—the Trident (enclosed) Gear Train?

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50 EAST 42d ST., NEW YORK CITY

Atlanta **Boston** **Chicago**
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WATER METERS

ARCTIC—*a frost-bottom meter for Domestic Services.*

KEYSTONE—*an all bronze meter for Domestic Services.*

EUREKA—*a current meter for large and rapidly flowing volumes of water.*

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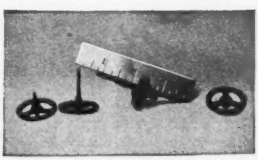
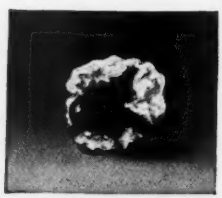
What Freezing Did Not Do

These two pictures show the intermediate gears of a Worthington Model "G" Meter. In one the train is encased in a solid block of ice, just as the parts were taken out of a completely frozen meter. After the ice melted the other photograph was made to show that no damage was done. Gears, train plate and casing, all came through the freezing totally unharmed. The only parts which suffered were four little bronze frost clamps, replaceable for a few cents. This shows some of the things that do *not* and *cannot* happen when a Worthington meter freezes. Those little frost clamps are certainly cheap insurance against the ravages of zero weather.

WORTHINGTON



Showing the gears, pinions and train plate after thawing. Not a single part has been warped or distorted in the least. The straight edge across the face of the train plate shows clearly that the original shape has not changed.



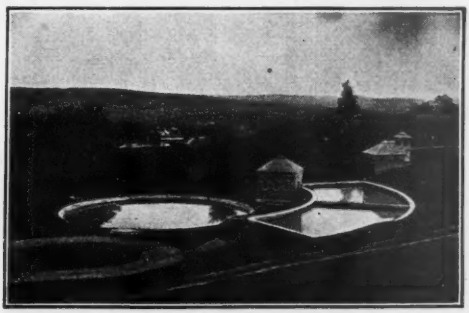
The intermediate train just after it was taken out of a standard Worthington meter. Note how completely the gearing is encased in ice.

WORTHINGTON PUMP AND MACHINERY CORPORATION

Executive Offices: 115 Broadway, New York City

Branch Offices in 24 Large Cities

CONSERVE
YOUR GREAT ASSET OF PURE WATER



The town or city with an abundant supply of pure, sparkling water is possessed of a most valuable asset which should be conserved and administered with greatest care. No matter whether the supply comes from an uncontaminated catchment area or has to be carefully filtered and treated before distribution, the supply should not be allowed to waste.

VENTURI METERS

have proved to be able and unceasing allies to thousands of towns and cities in the constant fight against waste and unauthorized use of water. When placed in well-planned locations in the supply and distribution mains, a constant and accurate knowledge of flow is available. The Venturi Register-Indicator-Recorder not only gives total flow but makes a permanent record on a 12" circular chart of every change of rate throughout every hour, day and night. Venturi Meters last as long as the pipe lines of which they form a part.

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Builders Iron Foundry

PROVIDENCE, R. I.

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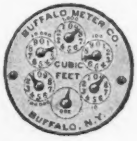
5/8 INCH NEW AMERICAN WATER METER

5/8 INCH NEW NIAGARA WATER METER

Niagara and American Meters are of the disc type. The Niagara Meter has a galvanized cast-iron outside casing; the American Meter has a bronze main casing with either a bronze base or a galvanized cast-iron base. The works in the three different casings are the same and interchangeable. Upon opening the meter at the bolted flange, each intermediate gear may be immediately removed from its bearing, the measuring chamber lifted from its seat, the strainer slipped out, or the register tried by turning the stuffing box gear. All submerged working bearings are protected against sand and sediment. The hard rubber measuring disc is reinforced with a metal plate. Purchaser has option of round reading or straight reading register indicating cubic feet, U. S. gals., imp. gals. or litres.

Round Reading Register

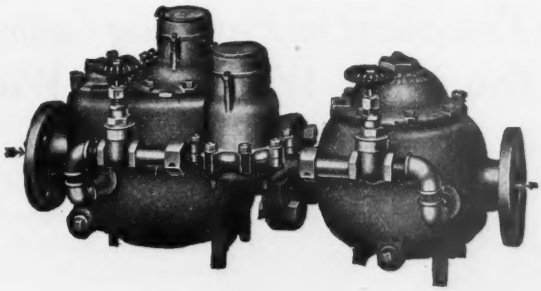


Straight Reading Register

BUFFALO METER CO.

ESTABLISHED 1892

2896 Main Street **BUFFALO, N. Y.**



The New Nilo

The new improved **Nilo Compound Meter** now comes equipped with a bronze body. This is a valuable addition to meter service for it eliminates the danger of corrosion and filling up due to the collecting of corrosive matter. Bronze being stronger than iron the gross weight of the meter is less, making it easier to transport, handle and install.

It also has two gate valves which allow the removal of the by-pass meter for cleaning or repairing without shutting off the line.

The controlling valve mechanism of the new **Nilo Compound Meter** is self contained and easily detached from the main body casings.

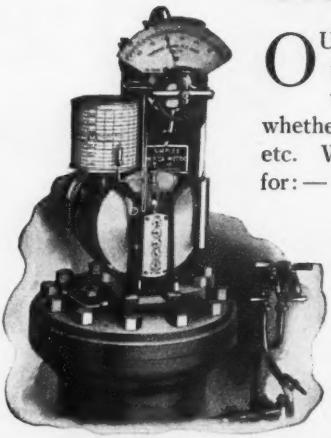
These three improvements make the **Nilo,** a long standing favorite, the unrivaled leader in its field.

UNION WATER METER CO.

Incorporated 1868

WORCESTER, MASSACHUSETTS

Is Your Pressure Low?
Are You Short on Pumping Capacity?
Do You Know Where Your Water Goes?



OUR Engineering Department will tell you how to determine your water distribution, how to find out whether or not new mains are required, etc. We can supply you with the means for: —

1. Checking up pump performance and determining slippage due to leaky plungers, defective valves, short stroking or other causes,
2. Measuring delivery of centrifugal pumps and figuring whether or not the station is up to efficiency,
3. Distributing proportionately the cost of water supplied to several districts,
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5. Detecting waste or pipe leakage,
6. Recording daily amounts of sewage handled and planning future extensions, etc., etc.

THE SIMPLEX METER

VENTURI, PILOT TUBE OR ORIFICE TYPES

THE importance of exact measurements by means of a Simplex Meter cannot be over emphasized. Mr. Jeffries, Chairman of the West Chester, Pa. Water Works Committee, was able, by checking the performance of his pumping engine with a Simplex Meter, to discover that due to the imperfection and wear in the valves the slippage amounted to 300,000 gallons of water per day. This represented a daily loss of $30.00, or in other words a daily saving of $30.00, or $900.00 per month, when the valves were put in order. The Simplex Meter thus paid for itself in a month's time.

Frequent repeat orders from satisfied customers who formerly used other meters are the best evidence of merit of the Simplex Meter.

We have had many years' experience in solving water flow problems involving all sorts of conditions, and we are at all times prepared to submit general layouts involving cost and capacity, and to make explicit and complete recommendations. Write for Bulletin N26.

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Manufacturers of Meters for Water, Sewage, and Other Liquids, Rate Controllers, Automatic Air Valves, Regulating Valves, and Hydraulic Apparatus of Special Design.

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"WATCH DOG" WATER METERS

ACCURATE *DURABLE*

DISC, CURRENT AND COMPOUND TYPES

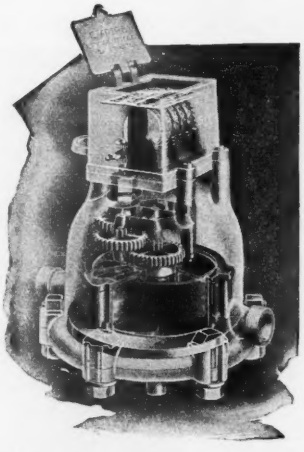
Inquiries Solicited

GAMON METER COMPANY

NEWARK **NEW JERSEY**

Something To Remember

The initial cost of any water meter is only paid once, but the maintenance cost goes on as long as the meter is in service. A meter that **stays** accurate, and keeps pulling in the revenue, year in and year out, with minimum stoppages or repairs, is the only economical one to buy.



The EMPIRE

has a fine record for that sort of work. It is practically in a class by itself for sustained accuracy, and endurance, and second to none for all round excellence. The initial cost of an **Empire** seems ridiculously low when compared to its high earning powers, its small maintenance expense and its long life.

What "They Say" About It

This is from a letter written by an official who has used **Empire** meters for over 20 years:

"We find **Empire** meters to be simple, accurate, and reliable, and the cost of upkeep less than any other make we have in use, and we have in service today nearly all makes." . . . "They prove to be the most economical in service of any meter we have, earning their cost in increased revenue many times over."

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OF NEW ENGLAND

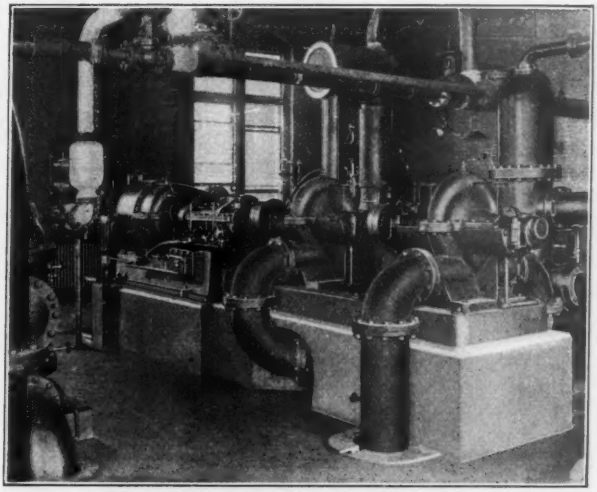
A few reasons why we solicit your inquiries on Water-Works Pumping Equipment:

First. — We make a specialty of furnishing Complete Water-Works Pumping Units of all types.

Second. — Total responsibility of installation is assumed by us.

Third. — We relieve the purchaser of every detail and turn the complete unit over to him under actual operation and with guarantee.

Fourth. — Every unit installed to date has exceeded its guarantee and has been completely accepted.



Turbine-driven Pump at the Arlington Station of the Metropolitan Water Works, Boston, Mass.

F. A. Mazzur & Co.

141 MILK STREET, BOSTON

FIFTY MILLION GALLON LOW LIFT PUMPING ENGINE

This Unit Is On Order For The Metropolitan District Commission, Ward Street Sewerage Station, Boston.

F. D. SMITH, Chief Engineer

DATA

35,000 gallons per minute capacity against 45 feet head.

Morris Machine Works Centrifugal Pump 36″ discharge, 40″ suction.

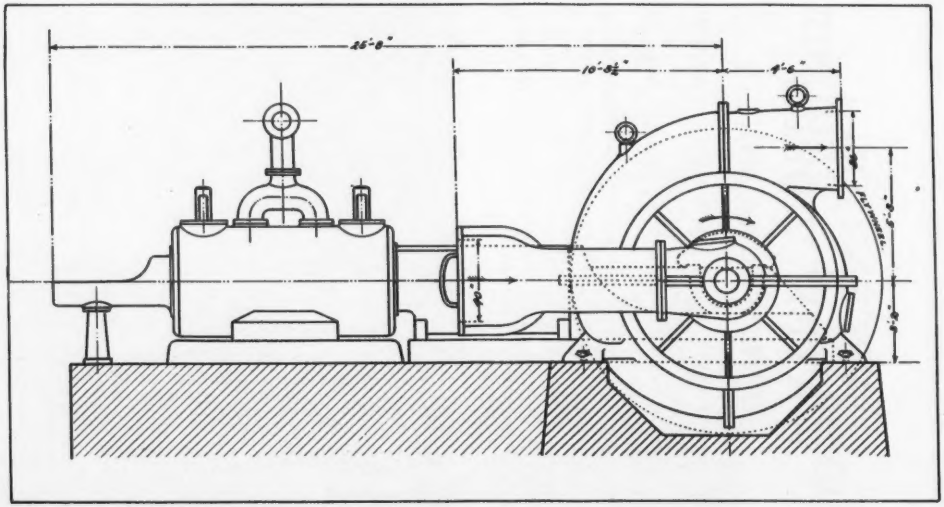
Nordberg Mfg. Co.'s Uniflow Engine, Cylinder 24″x 40″ at 150 r.p.m.

Steam Conditions 150 lbs. gauge 26″ vacuum, 1½% moisture.

Duty Guarantee 105,000,000 foot pounds per 1000 pounds steam.

Total Weight 130 tons = 2.6 tons per million gallons.

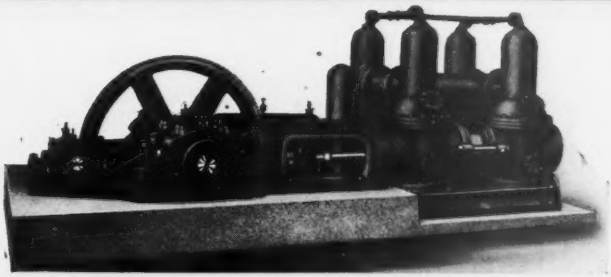
Cost of Pumping: $1.81 per million gallons pumped (steam costing 50c per 1000 lbs.).



There are many New England Waterworks having boilers for existing pumps where a similar unit would show superior economy.

STARKWEATHER & BROADHURST, Inc.

ENGINEERS AND CONTRACTORS **79 MILK STREET, BOSTON**



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WIRE TO WATER

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94 PEARL ST., BOSTON, MASS.

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OIL ENGINES

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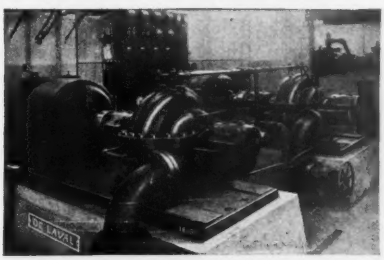
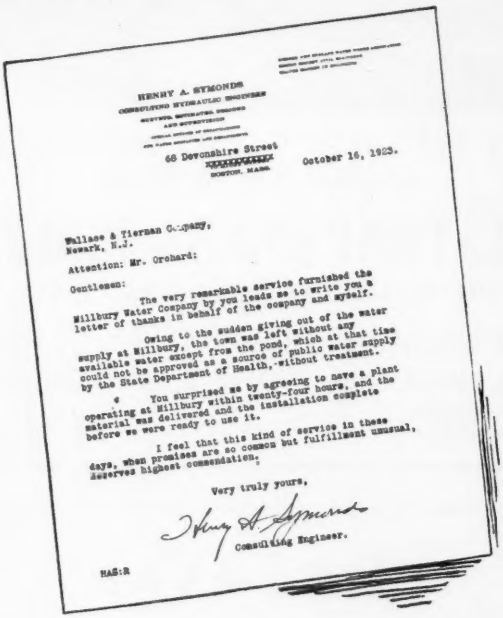


Typical Small Electrically Operated Centrifugal
Municipal Water Works Installation.

POWER EQUIPMENT COMPANY
BOSTON

Once More!



HENRY A. SYMONDS
CONSULTING HYDRAULIC ENGINEER

68 Devonshire Street
BOSTON, MASS. October 16, 1923.

Wallace & Tiernan Company,
Newark, N.J.

Attention: Mr. Orchard:

Gentlemen:

The very remarkable service furnished the Millbury Water Company by you leads me to write you a letter of thanks in behalf of the company and myself.

Owing to the sudden giving out of the water supply at Millbury, the town was left without any available water except from the pond, which at that time could not be approved as a source of public water supply by the State Department of Health, without treatment.

You surprised me by agreeing to have a plant operating at Millbury within twenty-four hours, and the material was delivered and the installation complete before we were ready to use it.

I feel that this kind of service in these days, when promises are so common but fulfillment unusual, deserves highest commendation.

Very truly yours,

Henry A. Symonds
Consulting Engineer.

HAS:R

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Water delivered through dirty pipes
may be a MENACE.

Incrusted water pipes mean inefficiency
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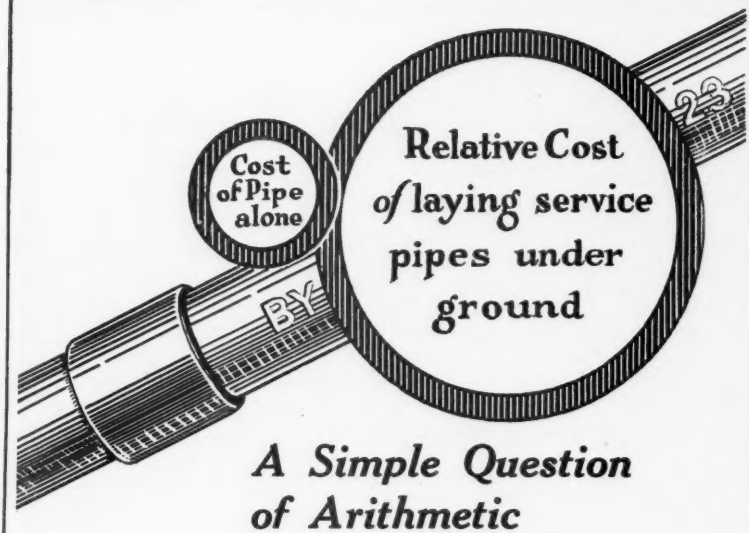

A Simple Question of Arithmetic

The cost of a length of service pipe is trifling compared with the cost of laying it. In case of failure of the pipe, the loss of water, labor of digging up and renewing a pipe, still further multiplies the installation cost.

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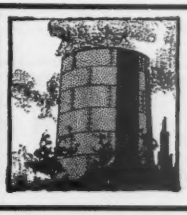

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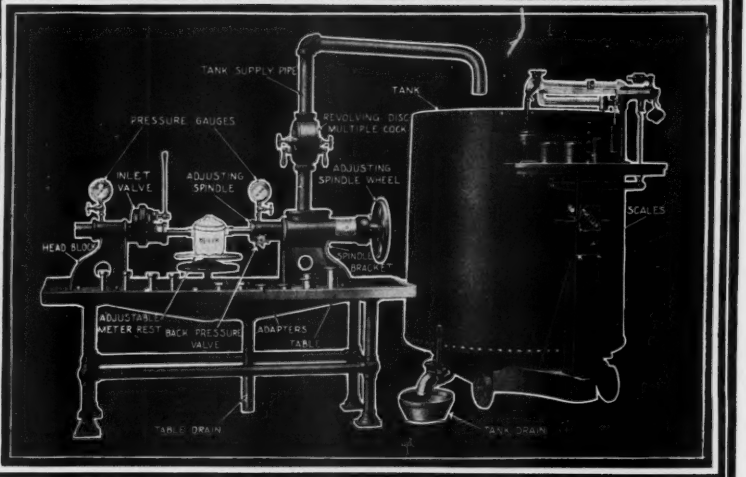

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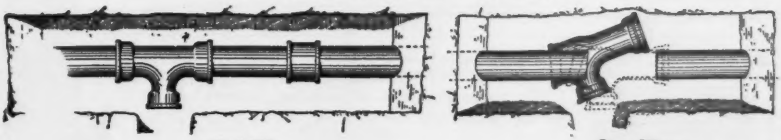

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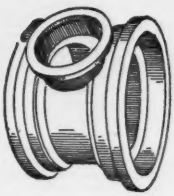

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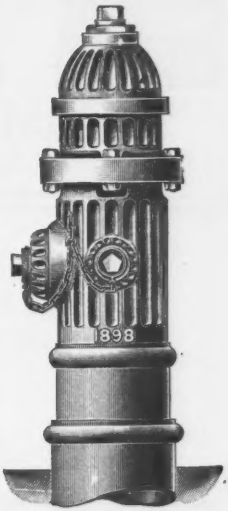

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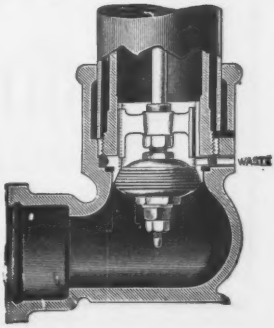

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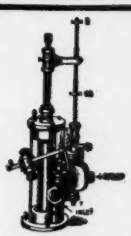

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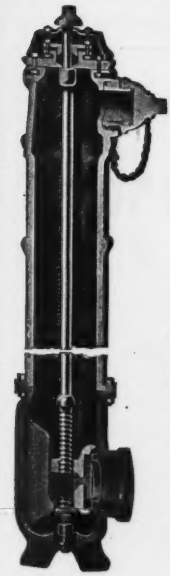

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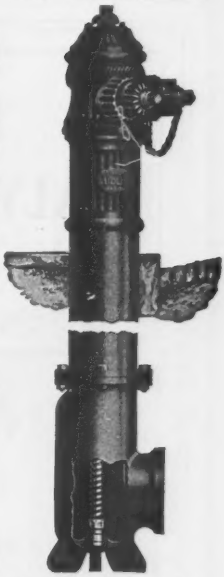

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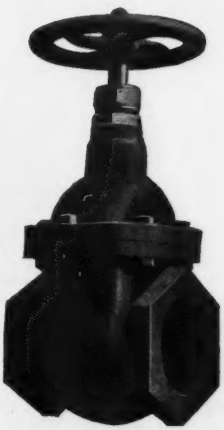

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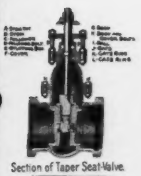
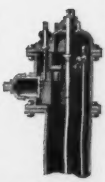
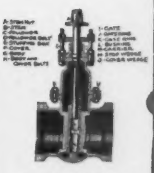


Section of Taper Seat-Valve.



Hydrant with Independent Nozzle Cut-off.



Section of Parallel Seat-Valve.

Section of Vertical Check-Valve.

Section of Vertical Foot-Valve.

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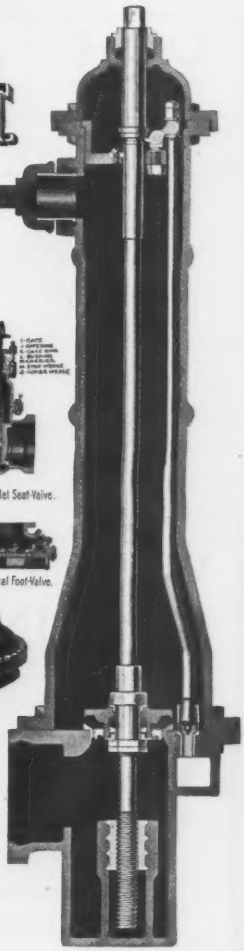

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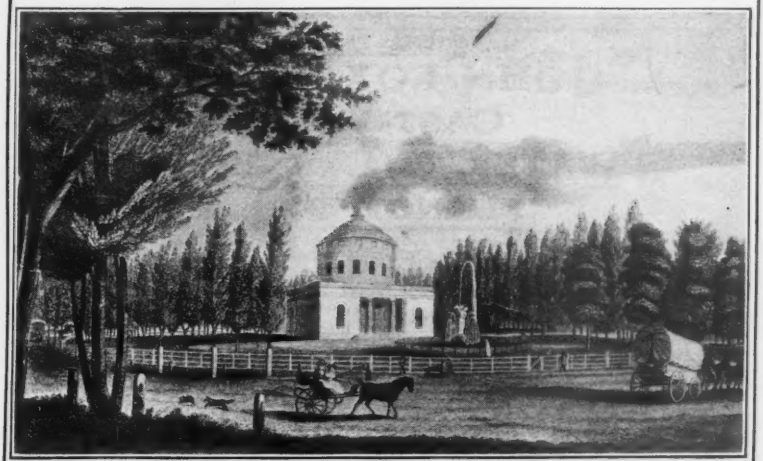

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In 1842 Charles Dickens wrote the above description of the Philadelphia Water Works. At that time cast iron pipe, in Philadelphia, had been delivering water faithfully for 25 years. Nor was its usefulness nearly over. In 1915 the pipe illustrated was removed, though still in good condition after almost a century of service, to make way for a line of larger capacity.

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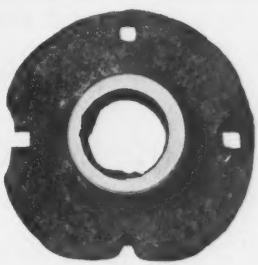

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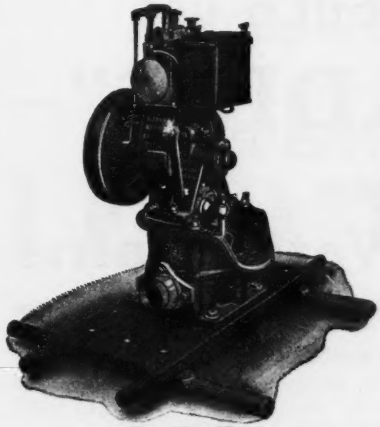

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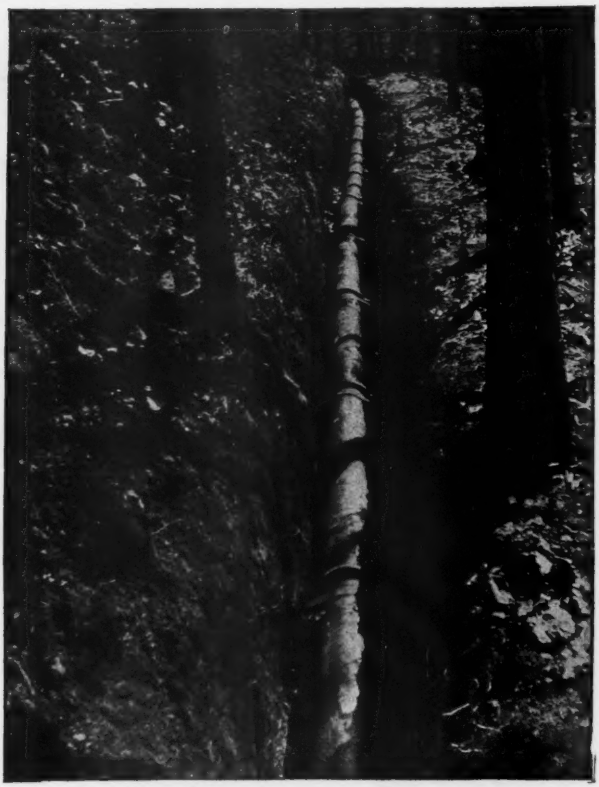

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ORGANIZED JUNE 12, 1882.

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